Control ENGINEERING

INSTRUMENTATION AND CONTROL SYSTEMS

A McGraw-Hill Publication

Two Dollars

SEPTEMBER 1961

basic phenomena

SOLID

measurement

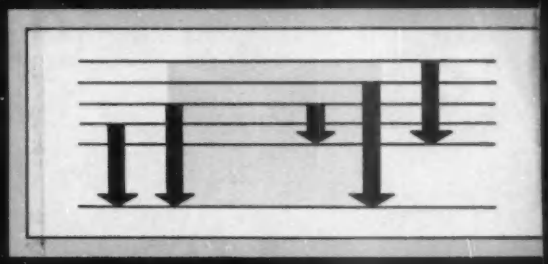
STATE IN

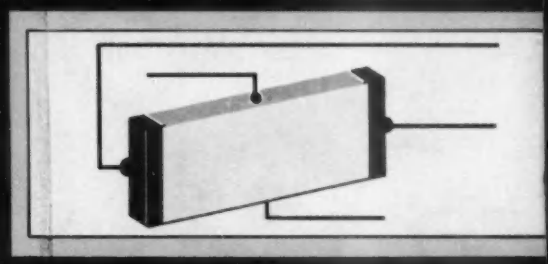
memory and logic

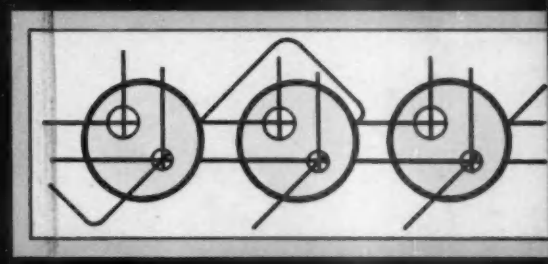
CONTROL

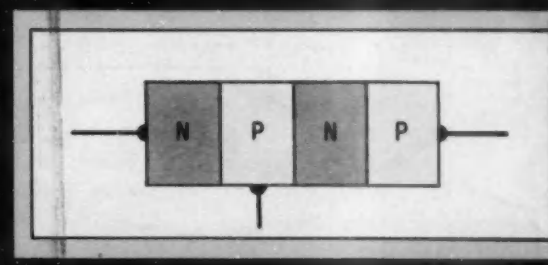
power control

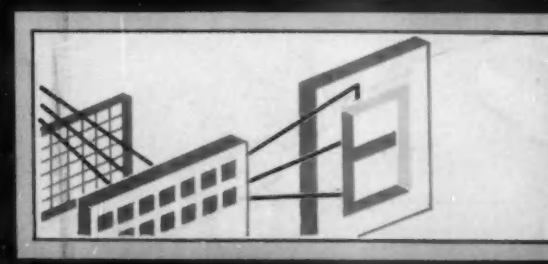
display













WHY MORE ENGINEERS ARE SPECIFYING LIBRASCOPE ENCODERS

New design features in Librascope encoders have sharply reduced noise and eliminated ambiguity, while adding many hours of usable life. Among other features: faster operating and slewing speeds, accuracy you can depend on. And Librascope encoders have proved reliable in more than 15,000 military and commercial installations. Librascope now builds 132 encoder models with a variety of capacities, output codes and case sizes. It's probable that one of these encoders will satisfy *your* shaft position-to-digital conversion requirements. For the details, tell Librascope's engineers your applications and requirements. They'll promptly recommend the best encoder for the job. Just write to Applications Engineering, Librascope, Glendale 1, California. *In a hurry? TWX us collect at BRB 9884.*

GENERAL PRECISION

LIBRASCOPE DIVISION | GENERAL PRECISION INC., GLENDALE 1, CALIFORNIA

CIRCLE 273 ON READER SERVICE CARD

This unique "extra" fifth digit...



...provides 100% over-ranging...ten times greater resolution at decade voltage points where other 4-digit voltmeters change ranges and lose one full digit of resolution.

The KIN TEL Model 501B 4-digit, over-ranging digital voltmeter measures DC from ±0.0001 to ±1000.0 volts to an accuracy within 0.01% of reading ±1 digit. An extra fifth digit in the left decade indicates "0" or "1" to provide ten times greater resolution at decade (1, 10, 100) voltage points than standard 4-digit voltmeters. Ranging and polarity indication are entirely automatic. The measured voltage, decimal point and polarity symbol are displayed on an in-line readout in a single plane – no superimposed outlines of "off" digits.

An adjustable sensitivity control permits decreasing sensitivity to allow measurement of noisy signals. Ten-line, parallel input printers can be driven directly, and converters are available for driving other types of printers, typewriters, and card or tape punches. The input impedance is 10 megohms at null on any range, and an input filter attenuates power-frequency ripple by 60 db. Stepping switches are DC-driven (as in telephone service) at 20 steps per second, are guaranteed to give at least two years of trouble-free service without maintenance.

The 501B is one of a complete line of KIN TEL digital instruments. Others include AC converters, AC and DC preamplifiers, ratiometers, comparators, and multi-channel input scanners.

IMPORTANT SPECIFICATIONS

Display...Six decades display 5 digits (Left digit "0" or "1" only), decimal point, polarity symbol. Ranging and polarity indication are automatic. Projection system readout employs bayonet-base lamps with 3000-hour minimum life rating. Readout contains no electronic circuitry and can be remotely mounted.

Automatic Ranges...±0.0001 to ±1000.0 volts DC in four ranges: 0.0001 to 1.9999; 02.000 to 19.999; 020.00 to 199.99; 0200.0 to 1000.0

Accuracy...0.01% ±1 digit (of reading).

Input Impedance...10 megohms on all ranges at null.

Reference Voltage...Chopper-stabilized supply, continually and automatically referenced to standard cell.

Stepping-Switch Drive...DC voltage within stepping-switch manufacturers rating applied by transistor drive circuit at rate of approximately 20 steps per second.

Controls...Three: on-off; sensitivity; and mode of operation (standby, normal, print auto, print remote).

Printer Drive...Built-in for parallel input printers. Automatic or remote.

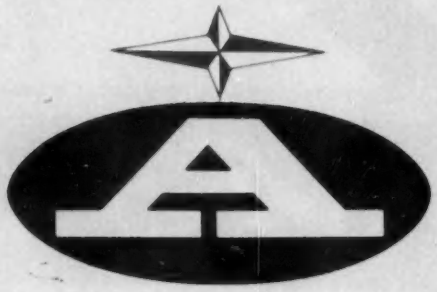
Dimensions and Net Weights...Control unit: 45 lbs, 5¼" H x 19" W x 16" D. Readout: 10 lbs, 3½" H x 19" W x 9" D.

Price: $2995

KIN TEL manufactures electronic instruments for measurement and control, and closed circuit TV. Representatives in all major cities. Write for detailed literature or demonstration.

KIN TEL
A DIVISION OF
COHU
ELECTRONICS, INC.

5725 Kearny Villa Road, San Diego 11, California, Phone: BRowning 7-6700



is for

ASTRODATA

Our business is data acquisition and processing

Astrodata Inc. is a new California corporation, but its people, products and achievements are well-known to the Western electronics industry. As Epsco-West, a Division of Epsco, Inc., this same group designed and produced over 50 reliable high-speed data systems in just three years. Using the same plant Epsco-West formerly occupied, ASTRODATA begins with fully-equipped facilities and an engineering team with demonstrated ability to solve your data handling needs.

Choice of the name ASTRODATA reflects the branch of space age technology in which our people are well recognized – data control systems and ancillary instrumentation. ASTRODATA systems include a complete timing system on the Pacific Missile Range, operational checkout system for the Atlas missile at both Vandenberg AFB and Cape Canaveral, a high-speed, high-accuracy, data handling system for Bell Labs for use in conjunction with Nike Zeus tests at New Mexico's White Sands Missile Range, an automatic digital temperature recording system for monitoring temperatures within an atomic reactor, and a high-speed digital acquisition and processing system which speeds space probes at Lockheed's Missile and Space Division. Standard products include a wide range of time code generating, translating and tape searching equipment, dual mode amplifiers for low-level commutation and a variety of solid-state, plug-in modules.

Significantly, ASTRODATA now offers nationwide sales and service. For more information concerning the talent and capabilities of our company, write for a copy of *"This is Astrodata..."* to Astrodata, Inc., 240 E. Palais Road, Anaheim, California.



ASTRODATA INC.

Successors to Epsco-West

ANAHEIM, CALIFORNIA

Control ENGINEERING

SEPTEMBER 1961
VOL. 8 NO. 9

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

SOLID STATE IN CONTROL
practice, progress, and potential

120 **What Solid State Means**
L. H. YOUNG of Control Engineering introduces the editorial theme with a summary of what solid state means, what the significant phenomena are, and how they can be applied.

BASIC ENGINEERING CONCEPTS

122 **Explaining Solid State Phenomena**
A. G. *MILNES* of Carnegie Tech explains how and why solid state devices work the way they do by reviewing physics and discussing each of the significant solid state phenomena.

MEASUREMENT

134 **Piezoelectric and Piezoresistive Strain Gages**
E. JONES of Kulite-Bytrex Corp. describes solid state strain gages and transducers, and tabulates some strain gage elements, accelerometers, pressure gages, and load cells.

138 **Hall Effect Transducers**
C. WOOD of Kearfott measures current, power, magnetic field strength, and position with a semiconductor Hall effect generator and lists transducers now available.

142 **Solid State Radiation Sensors**
E. WORMSER, R. A. FARRALL, and P. F. DONOVAN investigate radiant energy measurement—infrared, visible, and nuclear—and give facts on kinds of detectors in use.

145 **Semiconductor Thermometers**
A. *NUSSBAUM* of Minneapolis-Honeywell senses temperatures, especially in the cryogenic region, using germanium probes structured to fit range and sensitivity needs.

DATA TRANSMISSION

147 **Light: A New Communication Medium**
G. C. *DACEY* of Bell Telephone Labs tells about the optical maser that can produce kilowatts of narrow beam coherent light and carry many millions of data channels.

DECISION MAKING AND STORAGE

150 **Where Solid State Fits Into Control Memory**
E. J. KOMPASS of Control Engineering considers the memory function everywhere in the control system, and the solid state memory devices that fit various needs in the loop.

156 **New Approaches to Control Logic**
J. B. HANGSTEFER of Solid State Products stresses the advent of semiconductor switching as the factor that gave real impetus to control application of logic techniques.

160 **What About Cryotronics?**
M. L. *COHEN* of A. D. Little predicts here cryotronic switching circuits will probably first be used in large computer memories because of their nanosec speed and unit gain.

Continued on next page

POWER MODULATION AND GENERATION

163 **Power Control With Semiconductor Devices**
B. MOKRYTZKI et al. of Westinghouse employ power transistors and silicon controlled rectifiers as power modulators that amplify small signals to drive actuators for control.

173 **Solid State Power Supplies**
G. HUNRATH of U. S. Army Signal R&D Lab uses silicon photovoltaic cells and thermocouples to convert solar energy and heat into electricity for powering equipment.

178 **Temperature Control With Thermoelectrics**
W. R. STUBSTAD of Collins Radio tries out thermoelectric devices, based on Peltier effect, in practical applications for cooling enclosures and critical electronic components.

INFORMATION DISPLAY

180 **Displaying Data by Electroluminescence**
M. KRAWITZ and *E. O. STONE* of Sylvania put electroluminescence—nonthermal radiation by electric excitation—to work in display, and classify available EL displays.

MOLECULAR ELECTRONICS

183 **Molecular Electronics—New Concept for Control**
H. V. NOBLE of Wright-Patterson Air Force Base proposes doing away with circuit components and wiring, and making a complete function from a solid state block.

WHAT'S NEW IN THE CONTROL FIELD

23 **Newsbreaks in Control**
H-290 on-line in economic dispatch; molecular slide rule; substitute for paper tape.

25 **Computer Software—Special News Report**
- **Boon for the User**
  Users find the programming packages become more important than the computer.
- **Survey of Automatic Programming Systems**
  Tabulation of compilers available or soon to be available and the machines they fit.
- **Survey of Application Programs**
  Tabulation of the commercially available programs that can solve broad data problems.

31 **Medical Electronics**
Report on a booming new field as seen at sessions of a New York national conference.

40 **Around the Business Loop**
Westinghouse organized for push in computer control; Greece's market for instruments.

---

21 **Control Personality—CLARENCE M. ZENER**
He asks the questions that haven't been asked before to develop solid state theory.

115 **Industry's Pulse—Solid State Devices**
Solid state devices are appearing at a fantastic rate as engineers mechanize the effects.

186 **New Product Developments**
Eight nameplates in 5 in. square panel possible with miniature solid state annunciator.

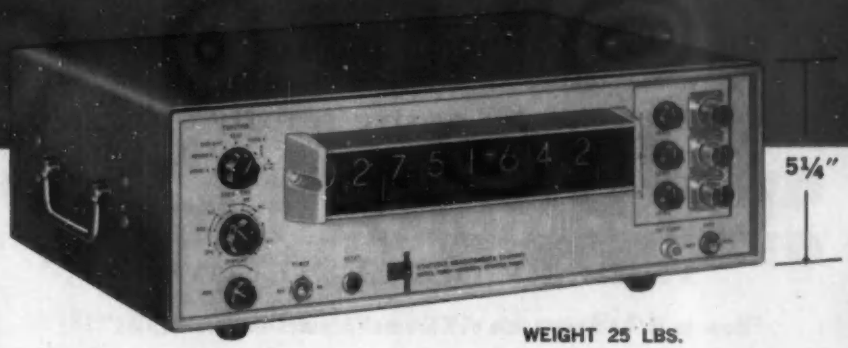
245 **Abstracts of Technical Papers**
Two papers describe digital speed regulating systems that may replace analog systems.

10 Shoptalk
14 Feedback
239 Catalogs & Bulletins
249 New Books
257 Meetings Ahead
260 Reprints

CONTROL ENGINEERING, September, 1961, Vol. 9, No. 9. Published monthly by McGraw-Hill Publishing Company, Inc. Executive, editorial, circulation and advertising offices: 330 West 42nd Street, New York 36, N. Y. Printed in Albany, N. Y.; second class postage paid at Albany, N. Y. and at additional mailing offices. U. S. subscription rate for individuals in the field of publication: $3 a year. Further details p. 6. POSTMASTER: Please send Form 3579 to Fulfillment Manager, Control Engineering, 330 West 42nd Street, New York 36, N. Y.

Another CMC First...

100 mc SOLID STATE Universal Counter-Timer



WEIGHT 25 LBS.

KEY SPECIFICATIONS

FREQUENCY
0 cps to 100 mc

TIME INTERVAL
0.02 μsec to 10^9 sec

PERIOD
0 cps to 10 mc

INPUT SENSITIVITY
1.0v rms

GATE TIMES (FREQUENCY)
1 μsec to 10 sec in 8 decade steps or external. Reads in cps, kc, mc.

FREQUENCY OUTPUTS
0.1 cps to 1 mc output in decade steps

ACCURACY
±1 count ± stability
±10 nanosecond ± stability

STABILITY
Short term: ±1 part in 10^8
Long term: within 5 parts in 10^8

PRICE, F.O.B. FACTORY
$3,950; inline readout $200 extra

✲ SEVEN BASIC FUNCTIONS, including dc to 100 mc frequency measurements without heterodyning techniques ✲ Time interval measurements with 10 nanosecond resolution ✲ Straight or totalizing counting ✲ Frequency ratio measurement ✲ Period measurement ✲ Sensitivity better than 1.0v rms ✲ Power consumption 50 watts ✲ Decade countdown time base (no adjustments necessary) ✲ Two year free service warranty ✲ No vacuum tubes ✲ Connector on rear providing standard 1-2-4-8 BCD output for operating printer, punch, etc.

Model 728B is a production unit, not a showpiece prototype. Demonstrators are now in the hands of CMC engineering reps. Call, wire or write to arrange a demonstration. Complete technical data plus a copy of our new 20 page short form catalog is yours for the asking.

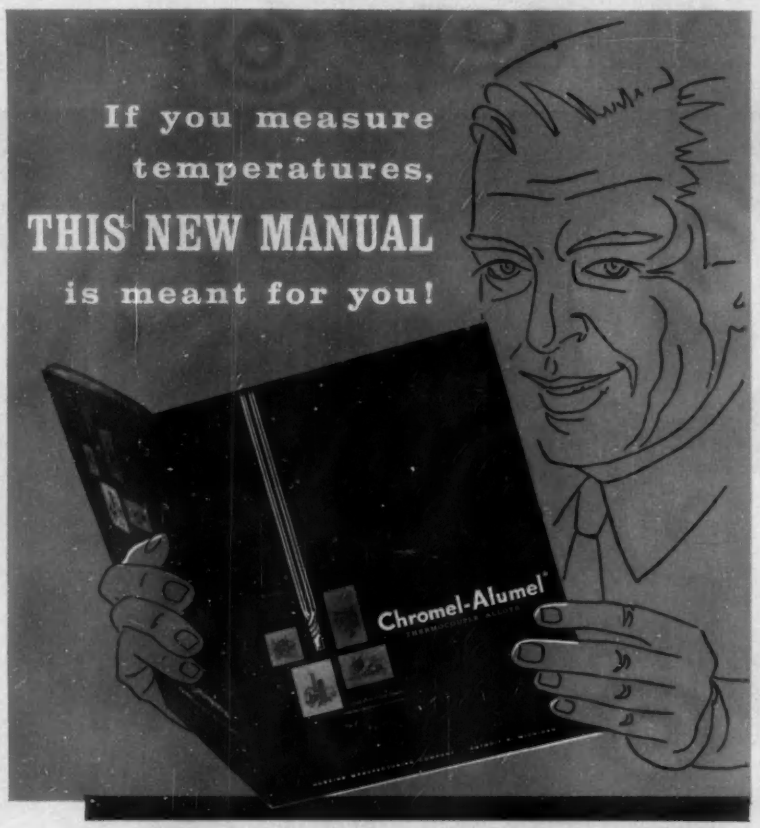
CMC 9 8 7 6 5 4 3 2 1 0

Computer Measurements Company

12970 BRADLEY AVENUE • SAN FERNANDO, CALIFORNIA
EMPIRE 7-2161

43

CIRCLE 5 ON READER SERVICE CARD



Contains detailed technical data on the entire family of

Chromel-Alumel*

THERMOCOUPLE ALLOYS

"How to make better use of Chromel-Alumel thermocouples"

That's the subject covered in detail by this new basic guide to more accurate temperature measurement. It gives complete information on the entire family of Chromel-Alumel thermocouple alloys—special purpose grades as well as Standard Guaranteed Millivoltage materials. It clearly states Hoskins Accuracy Guarantees—lists temperature-millivolt equivalents for Chromel vs Alumel—explains inspection and calibration procedures. What's more, it also contains much useful technical data on testing, fabricating and protecting thermocouples—covers special applications involving reducing and corrosive environments, high temperature oxidizing atmospheres, precision laboratory work, jet engines, nuclear reactors and cryogenic temperatures. So if you're concerned with accuracy, reliability, economy in measuring temperatures ranging from —300° to +2300°F., this manual is a *must* for you! Write for your free copy today.



**The names "Chromel" and "Alumel" are registered trademarks of*

HOSKINS MANUFACTURING CO.
4445 Lawton Avenue • Detroit 8, Michigan
In Canada: Hoskins Alloys of Canada, Ltd., Toronto, Ontario

Producers of Custom-Quality Resistance, Resistor and Thermo-electric Alloys Since 1908

Control ENGINEERING

SEPTEMBER 1961 VOL. 8 NO. 9

Published for engineers and technical management men responsible for the design, application, and test of automatic control systems.

BYRON K. LEDGERWOOD	*Editor*
HARRY R. KARP	*Managing Editor*
LEWIS H. YOUNG	*Senior Associate Editor*
EDWARD J. KOMPASS	*Associate Editor*
ROBERT F. HESLEN	*Associate Editor*
DEREK BARLOW	*European Editor*
STEPHEN S. LIVERS	*Assistant Editor*
MASON P. SOUTHWORTH	*Assistant Editor*
CAROLINE TAYLOR	*Copy Editor*
FLORENCE BAXLEY	*Editorial Assistant*
JACK GORDON	*Art Director*
DOUGLAS GREENWALD	*Dir. Economic Serv.*
G. B. BRYANT, JR.	*Mgr. Washington Bureau*
JOHN WILHELM	*Editor, World News*
MICHAEL J. MURPHY	*Los Angeles*

Consulting Editors

GORDON S. BROWN	*Cambridge, Mass.*
WILLIAM E. VANNAH	*Walpole, Mass.*
CHARLES E. FAULKNER	*Chicago, Ill.*
THEODORE J. WILLIAMS	*St. Louis, Mo.*
HARRY W. MERGLER	*Cleveland, Ohio*
W. W. GAREY	*Publisher*
J. G. ZISCH	*Advertising Sales Manager*
A. L. DE WEERDT	*Circulation Manager*
W. C. CARMICHAEL	*Business Manager*

PRINT ORDER THIS ISSUE 34,789

Published monthly by McGraw-Hill Publishing Company, Inc. Founder James H. McGraw (1860-1948). EXECUTIVE, EDITORIAL, CIRCULATION, and ADVERTISING OFFICES McGraw-Hill Building, 330 West 42nd Street, New York 36, N. Y. Telephone: LOngacre 4-3000. Teletype: TWX N. Y. 1-1636. Cable address McGRAW-HILL, N. Y.

OFFICERS OF THE PUBLICATIONS DIVISION: Nelson L. Bond, President; Shelton Fisher, Wallace F. Traendly, Senior Vice Presidents; John R. Callaham, Vice President and Editorial Director; Joseph E. Allen, Vice President and Director of Advertising Sales; A. R. Venezian, Vice President and Circulation Coordinator; Daniel F. Crowley, Vice President and Controller.

OFFICERS OF THE CORPORATION: Donald C. McGraw, President; Hugh J. Kelly, Harry L. Waddell, Executive Vice Presidents; L. Keith Goodrich, Executive Vice President and Treasurer; John J. Cooke, Vice President and Secretary.

Printed in Albany, N. Y.; second-class mail postage paid at Albany, N. Y. and at additional mailing offices. Title ® reg. in U. S. Patent Office. © Copyright 1961 by McGraw-Hill Publishing Co., Inc. All rights reserved, including the right to reproduce the contents of this publication, either in whole or in part.

TITLE AND COMPANY CONNECTION MUST BE INDICATED ON SUBSCRIPTION ORDERS forwarded to address shown in box below. Publication is available only by paid subscription. Publisher reserves the right to refuse nonqualified subscriptions. Single copies, 75¢, except $2 for September issue. U.S. and Canada one year, $5. Foreign: one year, $15.

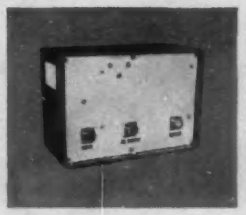
UNCONDITIONAL GUARANTEE: Our aim is to provide subscribers with a useful publication. Your comments and suggestions for improvement are encouraged and will be most welcome. The publisher, upon written request, agrees to refund the part of the subscription price applying to the remaining unfilled portion of the subscription.

SUBSCRIBERS: Please address all correspondence, change of address notices, subscription orders or complaints to Fulfillment Manager, CONTROL ENGINEERING, 330 West 42nd Street, New York 36, N. Y. Change of address notices should be sent promptly: provide old as well as new address; include postal zone number, if any. If possible, attach address label from recent issue. Copies of publications are addressed one to two issues in advance; therefore please allow one month for change of address to become effective.

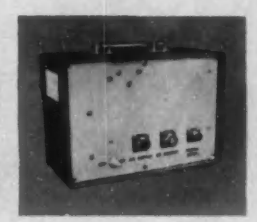
POSTMASTER: Please send form 3579 to Fulfillment Manager CONTROL ENGINEERING 330 W. 42nd St., N. Y. 36, N. Y.



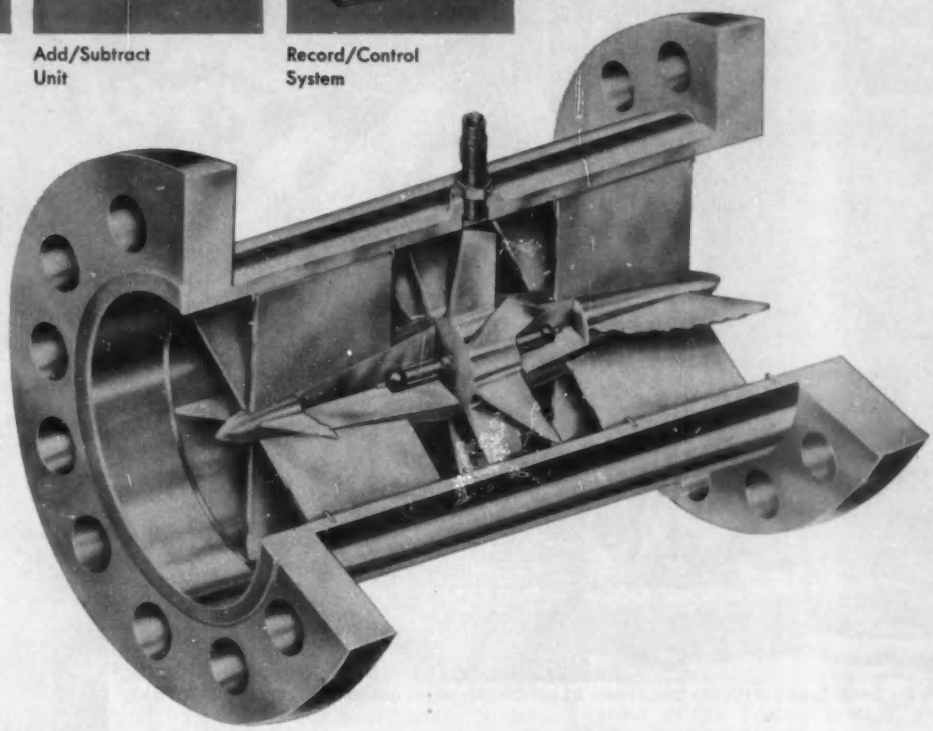
Totalizer/
Transmitter



Add/Subtract
Unit



Record/Control
System



CORROSIVE AND ABRASIVE FLUID FLOW ACCURATELY CONTROLLED

...even with reversals in flow direction

The Halliburton Turbine Flow Meter is a rugged, in-line instrument designed to electronically measure the flow of corrosive and abrasive fluids. It is designed for minimum maintenance and *no lubrication*. Companion readout equipment available for the Flow Meter includes:

ADD/SUBTRACT UNIT which utilizes the Flow Meter's unique ability to accurately measure fluid flow in either direction. This unit transforms flow data transmitted from the Flow Meter into a constant inventory reading of *any* storage system while it is being filled or drawn upon.

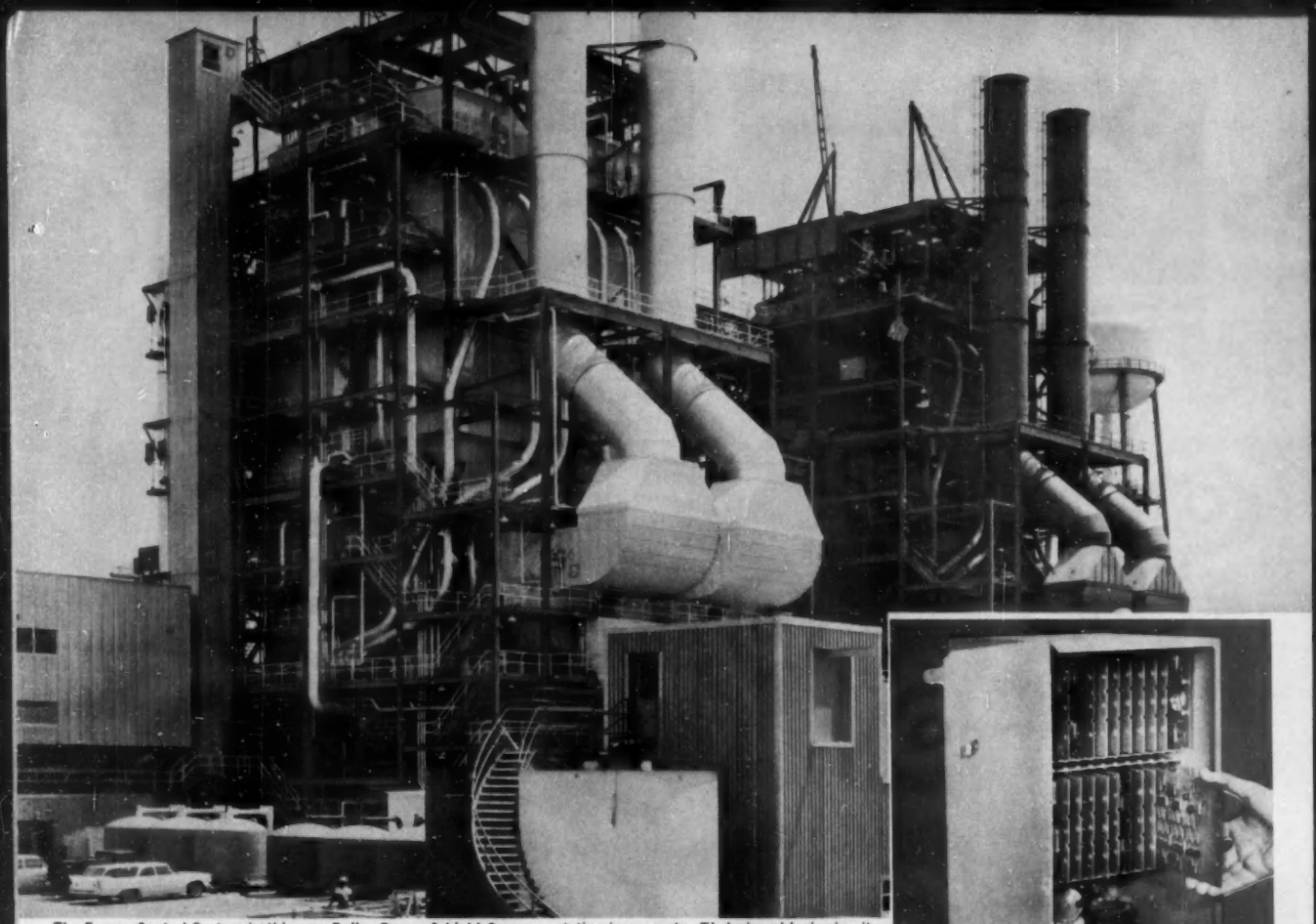
The new Halliburton Flow Meter Brochure tells the full story of these two new instruments plus the Flow Analyzer, Rate Meter, Totalizer/Transmitter, Batch Indicator, and Record/Control System. Write for a copy today to...

SPECIAL PRODUCTS DIVISION

New ideas...
reliable products...
seasoned experience...

Halliburton
COMPANY • DUNCAN, OKLAHOMA

CIRCLE 7 ON READER SERVICE CARD



The Forney Control System in this new Dallas Power & Light Company station incorporates TI-designed logic circuits.

Solid-State Logic Circuit Proved in 26-year Accelerated Life Test

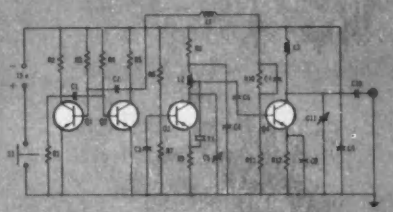
The critical control necessary in maintaining electric power generating plants — on-stream — is most important at the fuel ignition point. The fuel burner, therefore, must have constant, dependable supervision. To obtain fail-safe burner control a new Texas power station will supervise its fuel burning equipment with modern TI solid-state circuitry. This same circuitry has accomplished one year in-plant operation. Prior to actual installation the burner control circuitry was given an accelerated 26-year life test — both final in-plant operation and life test proved extreme reliability. This same system is now being applied in three other power stations and is scheduled for more in the near future. Installed in-doors or out, these control systems are virtually unaffected by environment. TI-designed logic control circuits are now serving public utilities, petroleum refiners, chemical processors — even the home appliance user. May we tell you more about this as well as other TI circuit applications?

Forney Engineering Co. of Dallas, working with TI's Apparatus division, installed this solid-state burner control at Dallas Power & Light Company's North Lake station. Using transistors, resistors, and other components from TI Transistor Products and Components divisions, this fail-safe controller eliminates relay system upkeep. It is applicable for existing semi-automatic power plant operation or future total computer operation and can be maintained by present personnel with standard test equipment.

TEXAS

How To Improve Control Performance With TI Circuits

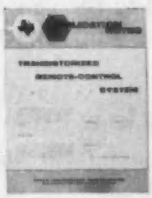
Transistorized *Remote-Control System*



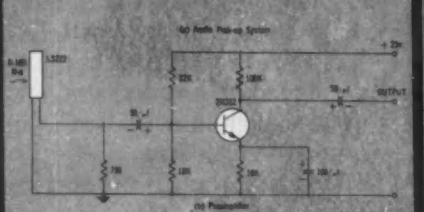
This remote-control system was designed for maximum performance consistent with simple circuitry. The Application Note offered below tells you how this system uses an economical selection of all components to provide the performance necessary in solving many remote-control problems.

The high-frequency capabilities of TI 2N1107 and TI 2N1370 germanium transistors make this system particularly attractive when low circuit power consumption is important.

Write for this Application Note today.



Silicon Photovoltaic Light Sensor

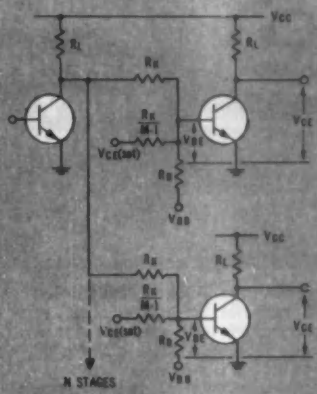


The applications for Texas Instruments LS 222 and LS 223 miniature light sensors are limited only by the designer's imagination. The Application Note offered below suggests a number of specific uses. In addition, it discusses theory and characteristics of silicon photovoltaic cells in general. The Note also points out the reliability and operational advantages of these devices over other types of light sensors.

Write for this Application Note today.

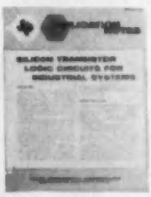


Silicon Transistor *Logic Circuit for Industrial Systems*



This TI industrial logic circuit, used in the Forney control system described on the facing page, is extremely versatile and has been adapted to many other control requirements. The Application Note offered below discusses a transistor-resistor digital logic circuit that is both economical and extremely reliable. The Note also discusses a design technique that demonstrates the feasibility of using high-reliability/low-cost TI silicon transistors in this industrial application.

Write for this Application Note today.

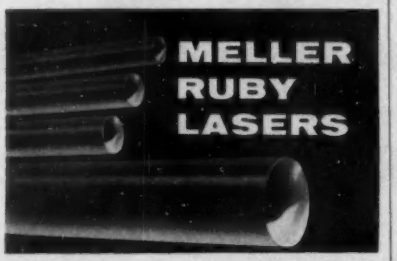


INSTRUMENTS
INCORPORATED

13500 N. CENTRAL EXPRESSWAY
P. O. BOX 5012 DALLAS 22, TEXAS

Contact your local TI sales engineer or authorized TI distributor for information on many other TI Application Notes and Reports available to you. You may prefer to write Texas Instruments Incorporated, Attention: Mail Station 231, outlining your specific requirements . . . for the immediate assistance of qualified technical sales engineers.

CIRCLE 9 ON READER SERVICE CARD



LAPPED . . . IN STOCK . . . IMMEDIATE DELIVERY! All material is laser quality, very slow grown, and well annealed for minimum strain. Doping is .04% chrome by weight. Orientation is within 1 degree . . . flatness ¼ wave or better . . . parallelism 6 seconds of arc.

STOCK SIZES CUT YOUR COSTS!
(ALL MELLER MATERIAL IS GUARANTEED TO LASER.)

(1) "C" axis parallel to cylinder axis: ¼" x 1½", ¼" x 2", ¼" x 2½", .200" x 2", ¼" x 3".

(2) "C" axis perpendicular to cylinder axis: ¼" x 2".

(3) 60° orientation: .320" x 7⅞", .625" x 5½"

For stock items or specials, write or call Adolf Meller Company, Box 6001, Providence, R. I. Tel. DExter 1-3717 (Area Code 401).

MELLER SAPPHIRE PRODUCTS

Synthetic Sapphires • Ruby Lasers & Masers
Alumina Powder

SHOPTALK

Seven candles on the cake

For the seventh September in a row, readers hold in their hands a copy of CONTROL ENGINEERING's annual theme issue, which this year is devoted to in-depth coverage of SOLID STATE IN CONTROL. To the editors, such an issue is an opportunity and a challenge. To the readers, the issue means principles and practices reduced to print. This issue was written by authorities in the fast growing, fast changing technology of solid state, and then edited by the staff specifically to meet the control engineers' needs.

CONTROL ENGINEERING now starts its eighth year. On second thought, perhaps we'll put eight candles on our birthday cake—one added to assure continued growth and service to our readers during the next year.

Jack gone—Jack here

Missing from the staff is Art Director Jack Gordon. Jack—who has designed the covers for every issue of CONTROL ENGINEERING since its start and laid out all the articles in these issues in pleasing patterns to enhance readability—has been hospitalized for some weeks with a "bum" back.

Jack's siege started shortly before September-issue time. Going from one art director to no art director is a drastic step-change disturbance. Before an ensuing transient even got started, however, magazine production got right back on setpoint. For this we thank Jack Marzullo, a stalwart in McGraw-Hill's Illustration Dept., who responded to our call for aid, moved up to Gordon's drawing board, and proceeded to package this issue. We like the results, and trust you will too. Thanks, Jack; hurry back, Jack.

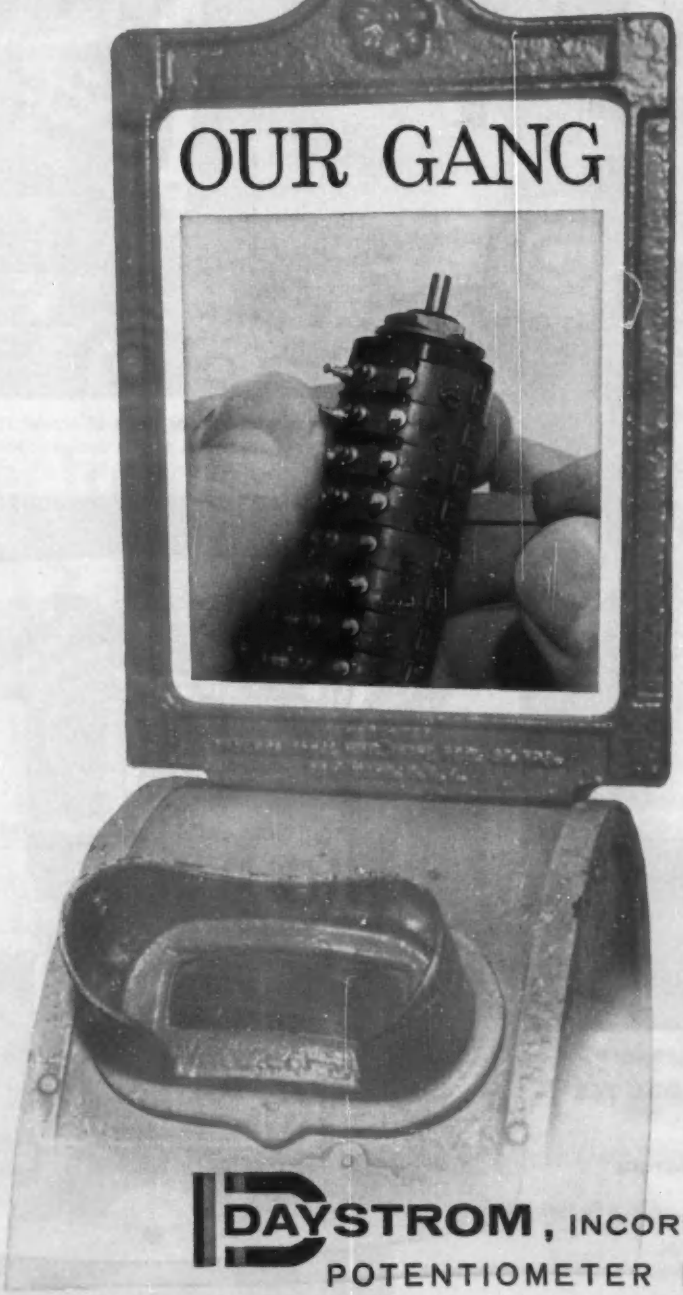
Following a dictum

Years ago, company founder James McGraw said, "An editor should wear out the soles of his shoes, not the seat of his pants." On CtE, too, editors hit the road to learn about new technology, new equipment applications, and new control problems—all of which finally redounds to the benefit of our readers as significant technical articles and up-to-the-minute news coverage.

Such travel includes weeks-long trips to the West Coast. Latest editor to make the cross-country trek is Assistant Editor Mason Southworth, who finishes his tour from Seattle to San Diego, including WESCON in San Francisco, just before Labor Day. Later in September Chief Editor Byron Ledgerwood will cover the ISA show in Los Angeles and meet with key control users and makers on the coast with the view to dovetailing their interests and activities with our long range editorial coverage.

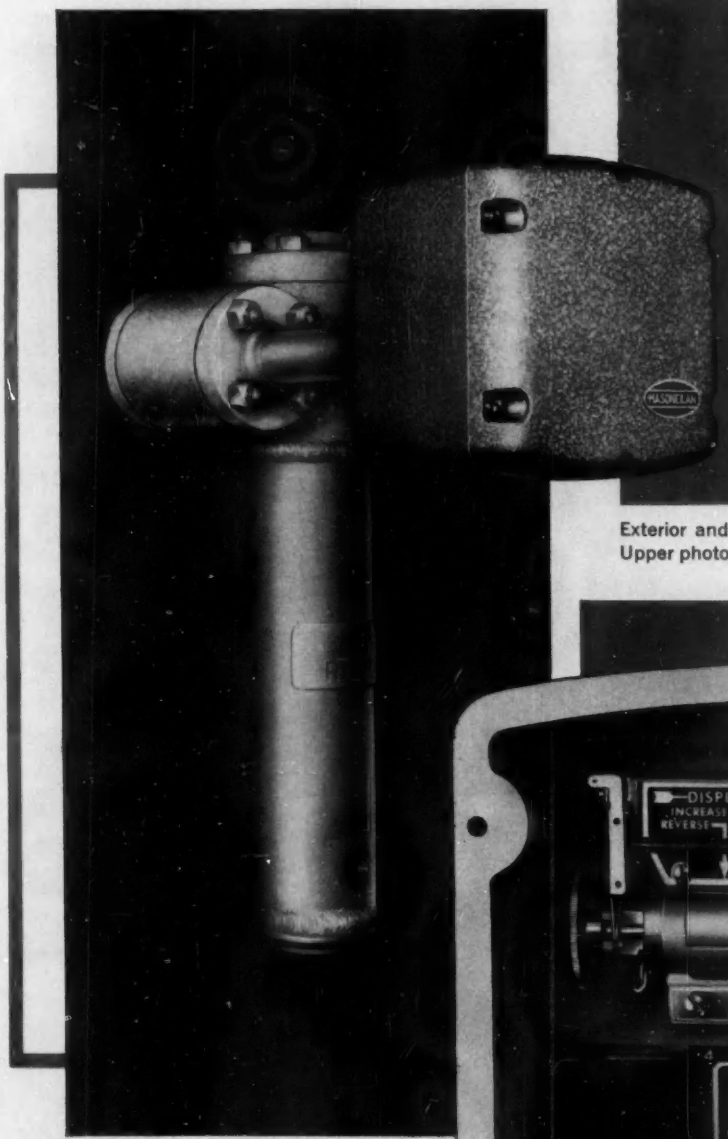
New Daystrom Series 319 Potentiometers Can Be Adjusted In Seconds After Ganging

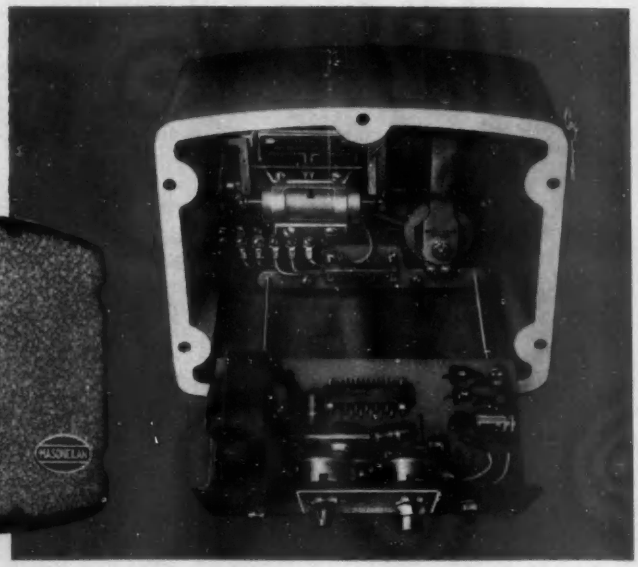
It can be done. **24 cups of the Daystrom 319 Series potentiometers ganged within six inches. *Most important,* phasing of individual cups can be accomplished after installation, and with no interference to adjacent cups. Results: finite adjustments • many hours and dollars saved in installation costs • re-phasing in a matter of seconds!—■—The Daystrom 319 Series is ideal for multi-channel applications. Exclusive Daystrom design techniques result in unusual stability to shock, vibration, and other severe environmental influences. The 319 is rated at 2 watts in *still air,* operates over a range of −55°C, to 150°C, is available in resistances from 100 ohms to 200 kilohms, and meets or exceeds all applicable MIL Specs. Send for further data.**



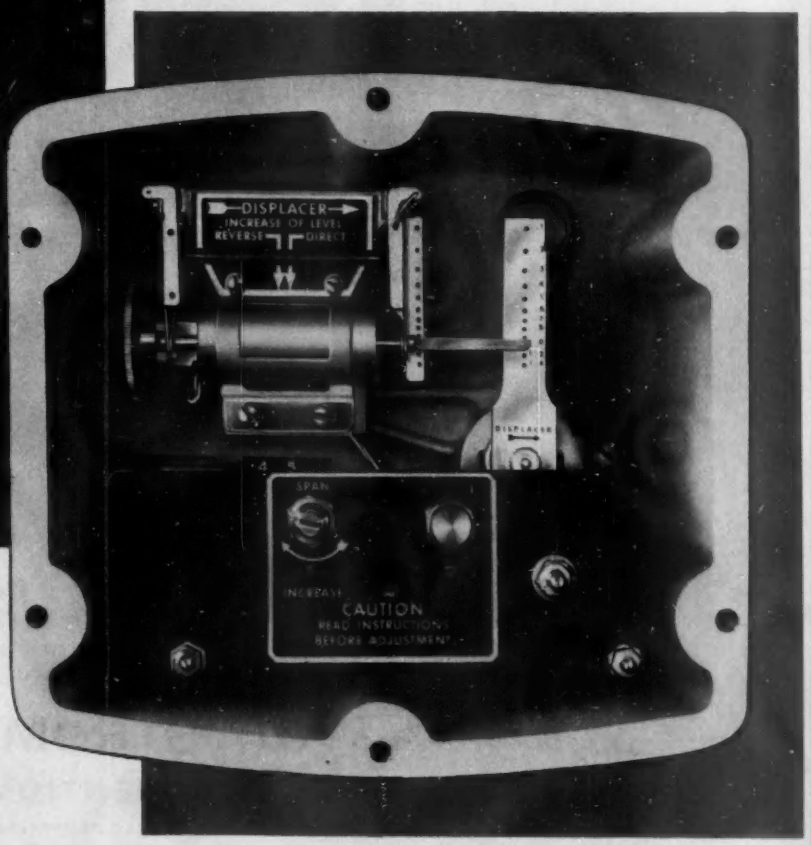
DAYSTROM, INCORPORATED
POTENTIOMETER DIVISION
ARCHBALD, PENNSYLVANIA • LOS ANGELES, CALIFORNIA

CIRCLE 11 ON READER SERVICE CARD 11





Exterior and interior views of Model 12520 Level Transmitter. Upper photo shows plug-in design of solid state amplifier.



See this and many more
MASONEILAN PRODUCTS
at the ISA Show
Los Angeles, California
BOOTH 828

Mason-Neilan Presents.....

A New High-Quality Electronic Liquid Level Transmitter

Making the proven advantages of displacement level measurement available for centralized electronic control systems

Mason-Neilan has utilized the best features of mechanical and electronic design to provide a new device for transmitting dc signals proportional to level variations.

This transmitter combines the time-tested, field-proven variable displacement measuring element made famous by the 12000 Series pneumatic level controllers, with an LVDT displacement transducer and a solid state amplifier. A choice of output signals permits use with any presently available electronic receiver — indicator, recorder or controller.

Consider these important features:

Accuracy . . . within 1%. High feedback serves to maintain accuracy and stability under changing ambient conditions. Torque tube assembly design insures true center of rotation — eliminates objectionable friction.

Reliability . . . solid state circuit with components of the highest quality.

Versatility . . . wide choice of output signals and level ranges. Left or right hand case mounting — reversible in the field. Selection of mounting types to meet all vessel requirements.

Ruggedness . . . sturdy aluminum explosion-proof instrument case provides maximum durability and protection to all internal parts.

Simplicity . . . adjustments are readily accessible and easily made. Plug-in amplifier assembly for convenient maintenance.

Complete data are yours for the asking. If you are now using, or contemplate using, electronic controls, we invite you to get in touch with a Mason-Neilan representative, or write to

MASONEILAN

Products that Work for Your Profit

MASON-NEILAN

Division of Worthington Corporation

51 NAHATAN STREET, NORWOOD, MASSACHUSETTS, U. S. A.

shortest
distance
between you
and
RELIABILITY!

LINE
ELECTRIC CO.
division of
INDUSTRIAL TIMER CORPORATION

RELAYS
FOR EVERY APPLICATION
Factory Tested for Reliability!

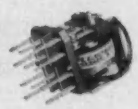
GENERAL PURPOSE
Open Type Relay. Up to 3PDT, 5 or 10 amp contact rating. Voltages up to 230 volts, AC or DC. Details in Bulletin 10.



GENERAL PURPOSE
Plug-In Type Relay. Contact arrangements up to 3PDT. 5 or 10 amp contact rating. Voltages up to 230 volts, AC or DC. Details in Bulletin 10.



PRINTED CIRCUIT Open
Type Relay. Up to 3PDT. 5 or 10 amp contact rating. Voltages up to 230 volts, AC or DC. Details in Bulletin 11.



LINE
ELECTRIC CO.
division of INDUSTRIAL TIMER CORPORATION

212 River Street, Orange, N. J.
Industrial Relays, Foot Switches, Buzzers, Coils
Phone: ORange 2-8200

FEEDBACK

Correspondence Closes the Loop

A recent article on guidance platforms generated mucho correspondence. This month Feedback is devoted exclusively to these communiques: a reader's criticism, the author's rebuttal, and the CtE-requested comments of an impartial expert.

Reader comments

To the Editor—

Dr. E. M. Fischel's article "Two vs Three-Gyro Guidance Platforms-I: How They Compare" (February '61, p. 92) provides a good description of these two types of platform mechanizations and the way accelerations, acting along all three axes, produce platform drifts due to gyro mass shifts.

The conclusions drawn by the author, however, are not all based upon a correct analysis of the details of his description. I refer, in particular, to Dr. Fischel's remarks concerning the comparison of the two-gyro and three-gyro inertial platforms in terms of their relative drift due to mass shifts in the presence of accelerations along all three axes. Dr. Fischel concludes that "under the effect of vertical accelerations (including gravity) the two-gyro platform has the smaller azimuth drift rate, whereas under the effect of horizontal accelerations, the three-gyro unit has smaller drifts."

The fact of the matter is, as indicated below, that the two-gyro platform has the smaller azimuth drift rate under assumed conditions for both vertical and horizontal accelerations.

Dr. Fischel's article shows that the two-gyro platform experiences a minor azimuth drift-producing error torque in each of the two gyros in the presence of an equal acceleration along each horizontal axis. Since these error torques are reduced statistically by the averaging mechanization indicated by Dr. Fischel, the net resultant azimuth drift is 70 percent of what either of these error torques, acting alone, would generate, or, to use the author's terminology, a 70 percent minor drift.

The three-gyro platform, however, as indicated by Figure 4 of the article, shows two error torques, acting on the same gyro, each resulting in a 70 percent minor drift, in the presence of the same horizontal accelerations as assumed above. These error torques add statistically to the equivalent of one minor azimuth drift.

The correct conclusion to be drawn from the author's description of this mass-shift-caused drift error, therefore, is that in the presence of either vertical or horizontal accelerations the plat-

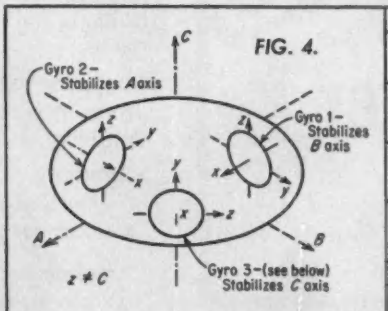
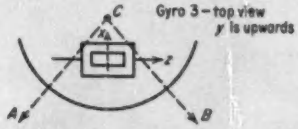


FIG. 4.

The coordinates of the platform are *A, B, C*

Those of the gyros are *x, y, z*, where *x* is always along the spin axis and *z* along the output axis

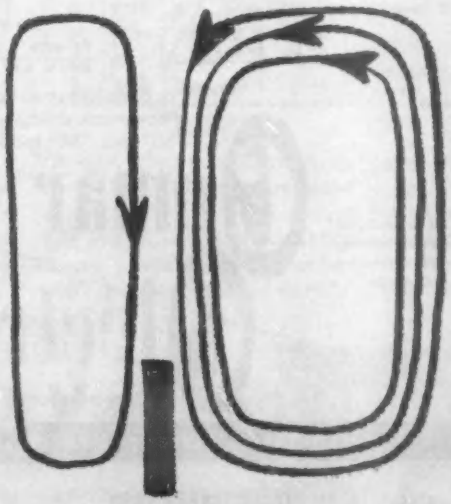


A mass shift along spin axis (*x*) is considered a major mass shift Ⓧ

A mass shift along *y* and *z* axes is considered a minor mass shift Ⓨ Ⓩ

Acceleration in direction of	Mass shift along	Torque produced around	Drift around
	Gyro 1 (*B* axis)		
A	Ⓨ Ⓩ	*z* *y*	(*y*)Ⓐ
B	Ⓧ Ⓩ	*x* *z*	(*y*)Ⓑ
C	*x* *y* *z*	*y* *x* —	— — —
	Gyro 2 (*A* axis)		
A	Ⓧ Ⓩ	*z* *x*	(*y*)Ⓐ
B	Ⓨ Ⓩ	*z* *y*	(*y*)Ⓐ
C	*x* *y* *z*	*y* *x* —	— — —
	Gyro 3 (azimuth)		
A	Ⓨ Ⓩ	0.7*y* 0.7*z* 0.7*y*	(*y*)ⓈⒸ
B	Ⓨ Ⓩ	0.7*y* 0.7*z* 0.7*y*	(*y*)ⓈⒸ
C	Ⓧ Ⓩ	*z* *x*	(*y*)Ⓒ

Metrisite... is the only  device available today that  provides a near-perfect combination of ideal transducer characteristics. The unusual properties of this remarkable new motion-sensing development are: extreme resolution...  easily measures one ten-millionth of an inch; minute operating force... absolute minimum bearing friction; negligible reactive force... a fraction of a milligram; true linearity... a proven accuracy of 1/10%; high electrical output... up to 100 volts without amplification; wide range of shapes and sizes... from sub-miniature on up; exceptional ruggedness... can meet military shock and vibration tests. Now, many of the obstacles that have plagued control technology can be eliminated. Write for Metrisite details.



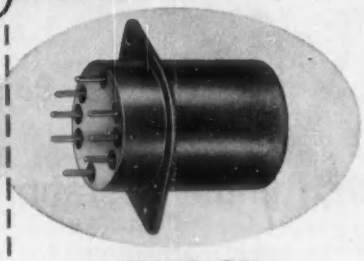
brush INSTRUMENTS
DIVISION OF CLEVITE CORPORATION
37TH AND PERKINS · CLEVELAND 14, OHIO

CIRCLE 15 ON READER SERVICE CARD

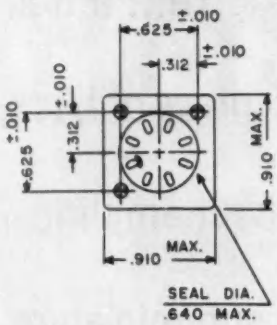
NEW HERMETICALLY SEALED DC RELAYS

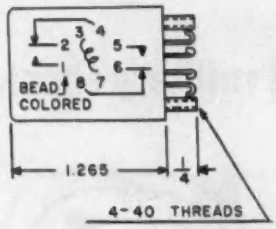
by Comar



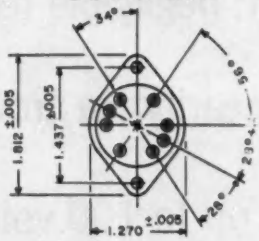


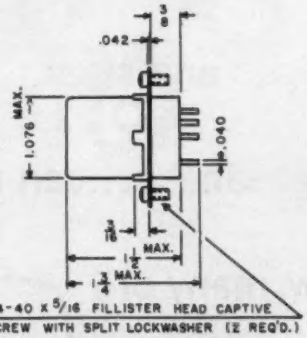
TYPE SS





TYPE SR





For complete specifications, operating conditions, coil data, etc., write for bulletins "SS" and "SR" today.

Ask for new Comar catalog illustrating many standard basic designs

Comar Electric

3349 ADDISON ST., CHICAGO 18, ILLINOIS

RELAYS • SOLENOIDS • COILS • SWITCHES • HERMETIC SEALING

FEEDBACK

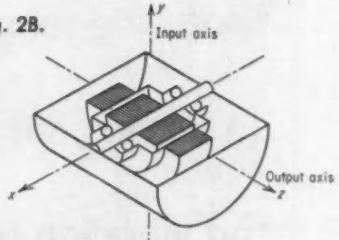
form drifts about the horizontal axes are the same for the two types of platforms, whereas the platform drift about the azimuth axis for the two-gyro platform is 70 percent of the azimuth drift for the three-gyro platform. This conclusion, moreover, is what one would expect from the fact that the two-gyro platform contains a total of four angular outputs (two for each gyro) compared to the corresponding total of just three angular outputs for the three-gyro platform (one for each gyro). This information redundancy for the two-gyro platform can be utilized in an averaging mechanization to reduce the drift by approximately 70 percent on a statistical basis of what it would be for a single axis of information. This reduction in two-gyro platform drift, of course, applies as well to most other sources of azimuth drift.

The author states that the two degree of freedom gyro experiences acceleration-caused drifts not present in single degree of freedom gyros because of play along the inner gimbal axis as well as because of gimbal deformation. These statements do not hold true for a fully floated gyro and gimbal, since the flotation fluid transmits all acceleration forces directly to the floated gyro wheel assembly and the gimbal;

(Continued on page 253)

(2) Azimuth gyro – rate integrating

Fig. 2B.



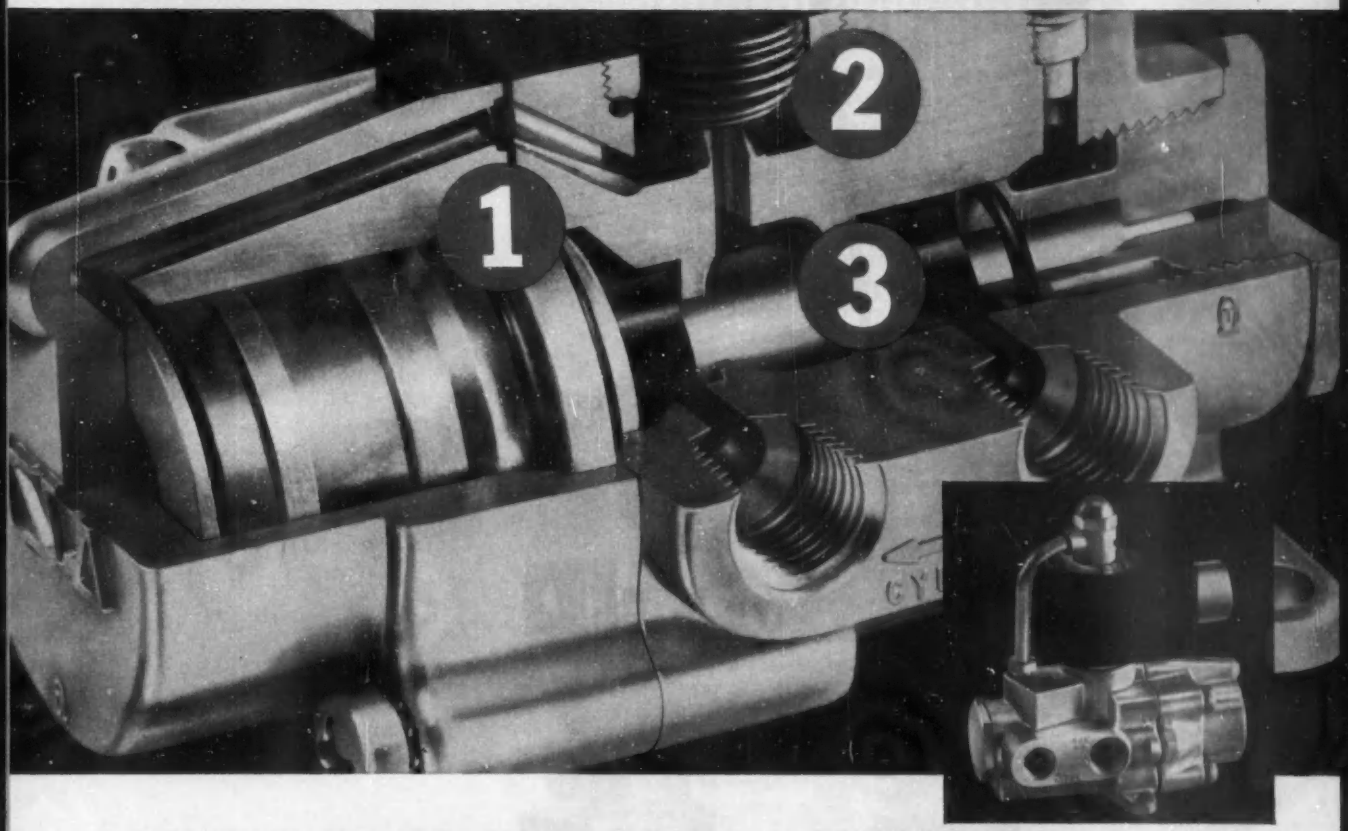
The coordinate system was turned with the gyro to the new position

Direction of acceleration along	Mass shift along	Torque produced around	Drift around
A axis	x ⊘ z	— z y	— ⊘ —
B axis	x y z	y x —	— — —
C axis (gravity)	⊗ y z	z — x	⊘ — —

Legend: ○ denotes minor shift or drift
● denotes major shift or drift

this is the way a valve is built to last

MILLIONS OF OPERATIONS:



NEW LOW-COST ASCO 4-WAY SOLENOID VALVES HAVE BEEN CYCLED MILLIONS OF OPERATIONS WITHOUT FAILURE

1. **TIGHT SEATING** with unique patented poppet-type seats—Patent Nos. 2,624,585—2,775,982
2. **RELIABLE OPERATION ASSURED**—failure to return due to residual magnetism is eliminated
3. **POWER OPERATION IN BOTH DIRECTIONS**—main valve not dependent upon return springs

Installation is simplified; the 8344 may be mounted in any position!

Poppet seals and a unique combination of metal-to-metal with resilient seating enable these and other ASCO 4-way solenoid valves to provide dead-tight shut-off, even on air, without lapping, grinding or close adjustments. The utter simplicity of design, eliminating return springs and power-operating the main valve in both directions, assures unprecedentedly reliable performance without maintenance for indefinite periods.

The new ASCO Bulletin 8344 valve is the latest embodiment of over half a century's design and development experience. Its low cost makes it economical even as a 3-way valve, with one pipe connection plugged.

Here are the pertinent statistics:

Pipe Size	Catalog No.	Solenoid Enclosures	List Prices†	Operating Information
¼"	83440	Std.	$48.00	Pressures: to 250 psi.
¼"	83444	Expl. proof	56.00	Temp: to 212° F.
⅜"	83441	Std.	48.00	Fluids: air, water, hydraulic oil
⅜"	83445	Expl. proof	56.00	

† Subject to trade and quantity discounts.

Other ASCO 4-way valves come in pipe sizes from ¼" to 1¼" for pressures to 500 p.s.i. For complete information write for Catalog 202, and see the hundreds of types of 2, 3, and 4-way solenoid valves available for immediate delivery from the world's largest stock.

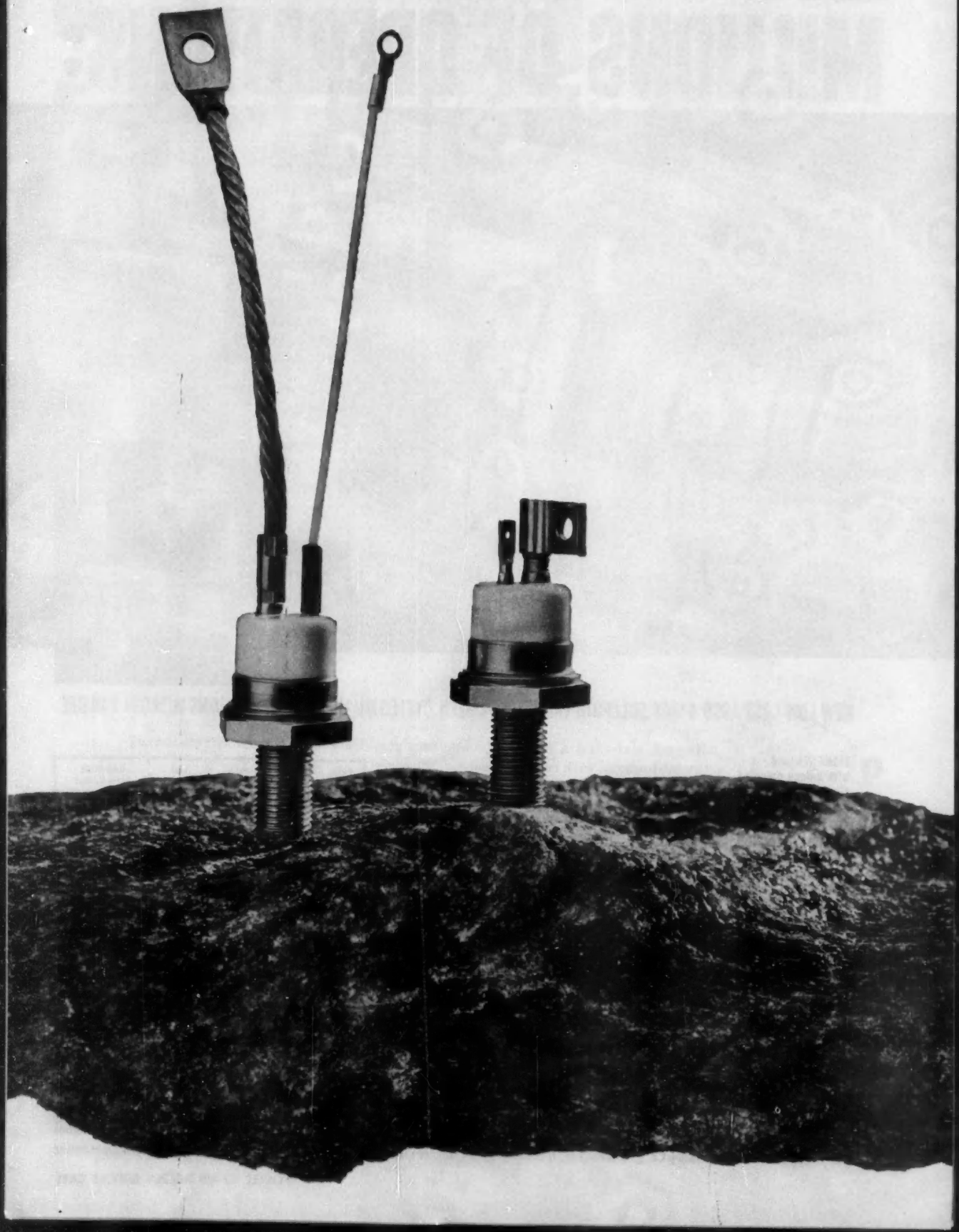
ASCO Valves

ASCO

DEPENDABLE CONTROL BY Automatic Switch Co. 50-G HANOVER RD., FLORHAM PARK, N. J. • FRONTIER 7-4000 • AUTOMATIC TRANSFER SWITCHES • SOLENOID VALVES • ELECTROMAGNETIC CONTROL

CIRCLE 17 ON READER SERVICE CARD

SEMICONDUCTOR NEWS: FROM WESTINGHOUSE AT YOUNGWOOD



Westinghouse announces new 70-amp ratings in "Rock-Top" Trinistor® controlled rectifiers

Highest rated flag type in the industry. Type 809 Trinistor controlled rectifier series, in both flag terminal and flexible lead types, now immediately available in production quantities at 70-amp ratings! Exclusive Westinghouse "Rock-Top" construction offers superior electrical and mechanical characteristics for greater performance reliability under all operating conditions. Provides positive protection against arcing at highest voltages. Exclusive new flag terminal design has lower weight . . . requires less headroom. Outstanding parameters include: ▪ 600 nanosecond switching time ▪ efficiencies in excess of 98% ▪ minimum noise level ▪ peak reverse voltages to 480 volts ▪ ideal parameters for high-speed static switch functions.

Industrial, commercial, and military applications include: high-frequency power generation; variable frequency controls; pulse generation; ignitron firing; welding control. Trinistors also replace thyratrons, contactors, magnetic amplifiers, relays.

For more information, or technical assistance, contact your nearest Westinghouse representative, or write: Westinghouse Electric Corporation, Semiconductor Department, Youngwood, Penna. *You can be sure...if it's Westinghouse.* SC-1046

For Immediate "Off-The-Shelf" Delivery, Order From These Westinghouse Distributors:

EASTERN

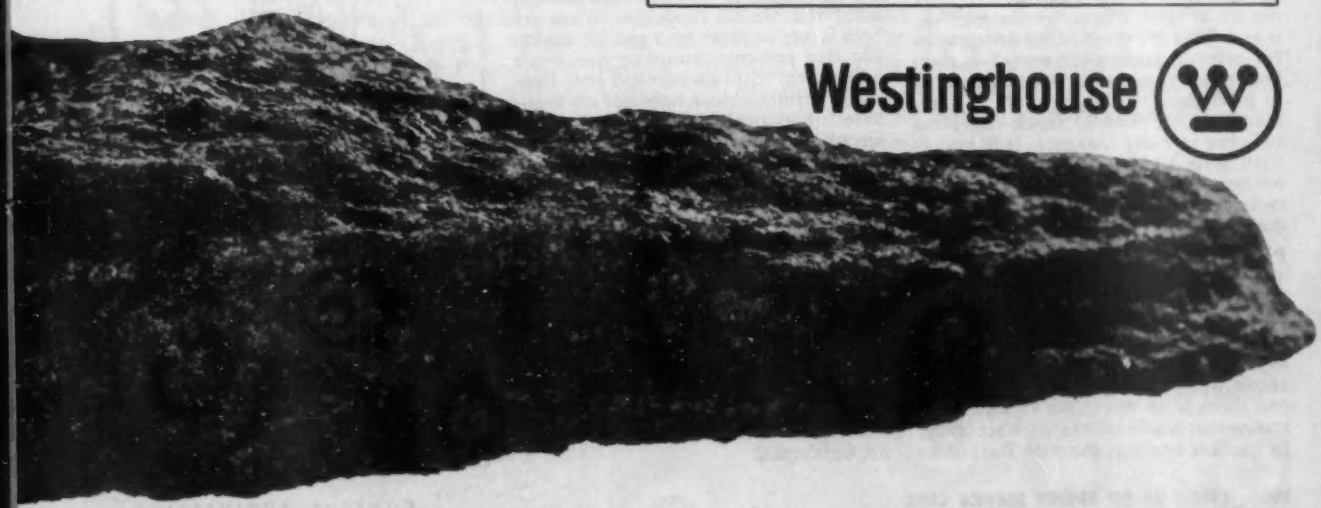
ACK SEMICONDUCTOR, INC. Birmingham 5, Ala./FA 2-0588
CAMERADIO Pittsburgh, Pa./EX 1-4000
CRAMER ELECTRONICS, INC. Boston, Mass./CO 7-4700
ELECTRONIC WHOLESALERS, INC. Melbourne, Florida/PA 3-1441
GENERAL RADIO SUPPLY CO., INC. Camden, N. J./WO 4-8560
GENESEE RADIO PARTS CO. Buffalo, N. Y./TR 3-9661
KANN-ELLERT ELECTRONICS, INC. Baltimore, Md./TU 9-4242
MILGRAY ELECTRONICS New York, N. Y./BE 2-4400
RADIO & ELECTRONIC PARTS CORP. Cleveland, Ohio/UT 1-6060
SCHWEBER ELECTRONICS Long Island, N. Y./PI 6-6520 Silver Spring, Md./JU 5-7023

MIDWESTERN

E.C.I. SEMICONDUCTORS, INC. Kansas City, Mo./WE 1-0829
ELECTRONIC COMPONENTS FOR INDUSTRY CO. St. Louis, Mo./WO 2-9916
HALLMARK INSTRUMENTS CORP. Dallas, Texas/RI 7-8933
INTER-STATE RADIO & SUPPLY CO. Denver 4, Colo./TA 5-8257
LENERT CO. Houston, Texas/CA 4-2663
MIDLAND SPECIALTY CO. El Paso, Texas/KE 3-9555 Phoenix, Ariz./AL 8-8254 Albuquerque, N. M./CH 7-0236
RADIO DISTRIB. CO. Indianapolis, Ind./ME 7-5571
SEMICONDUCTOR SPEC., INC. Chicago, Ill./NA 2-8860
S. STERLING CO. Detroit, Mich./BR 3-2900
UNITED RADIO, INC. Cincinnati, Ohio/MA 1-6530

WESTERN

ALMAC ELECTRONICS CORP. Seattle, Wash./PA 3-7310
ELMAR ELECTRONICS Oakland, Cal./TE 4-3311
HAMILTON ELECTRO SLS. Los Angeles, Cal./DR 2-9154 Palo Alto, Cal./DA 1-7541
NEWARK ELECTRONICS, CO. Inglewood, Cal./OR 4-8440

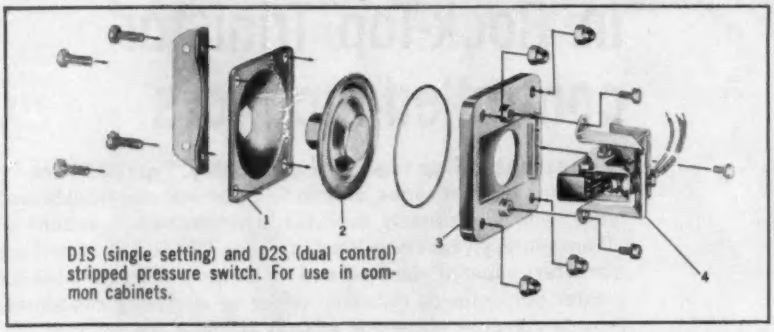


Westinghouse

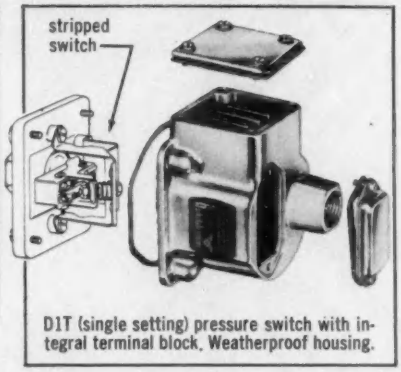
CIRCLE 19 ON READER SERVICE CARD

(Advertisement)

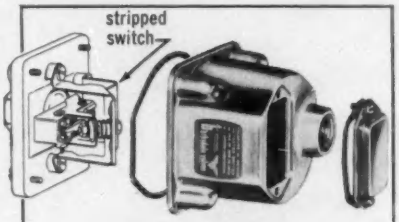
How to put 50% more accuracy into a pressure switch at 25% lower price



D1S (single setting) and D2S (dual control) stripped pressure switch. For use in common cabinets.



D1T (single setting) pressure switch with integral terminal block. Weatherproof housing.



D1H (single setting) and D2H (dual control) pressure switch with standard housing. Weatherproof.

The accepted standard of accuracy in pressure switches is ±1%. The new Barksdale diaphragm pressure switches are guaranteed for ±½% set and re-set accuracy. This instrument accuracy, unique proof (test) pressure characteristics, and remarkably easy servicing are accomplished by the use of a "basic unit" diaphragm assembly to which components are attached as required. The erector set principle permits production economies that are reflected in substantially lower prices. The entire concept of Barksdale pressure switches is the result of desired specification improvements as suggested by representatives of varied industries who were consulted before designing was begun.

The versatile basic unit

A leakproof, welded-metal sensing element (No. 2 in the photograph above) is surrounded by a heavy protective capsule (Nos. 1 and 3) which is independent of the sensing and switching elements. The hex of the pressure connection fits into a hex opening in the base of the capsule, preventing damage to the diaphragm should the unit be twisted during installation or removal. The standard pressure connection is ¼" npt female pipe fitting; ½" npt fitting is available when specified. The latter was requested by the petroleum industry to facilitate removal of paraffin accumulation and to permit attachment of switches directly to ½" pipe.

Diaphragms easily removable

Diaphragms may be removed without disturbing switch wiring, thus making it possible to change diaphragms to accommodate varying pressure requirements or to substitute diaphragms of different metals as fluid characteristics may demand. This feature cuts inventory costs for original equipment manufacturers because they need stock only diaphragms to meet their various pressure requirements rather than to stock complete switches in every category. It is important, also, to the petroleum industry because only diaphragms (not entire switches) need be carried by personnel doing field service.

Proof (test) pressures to 300 psi

The upper and lower sections of the diaphragm capsule are molded to fit the sensing element exactly. The top section prevents the diaphragm from stretching beyond normal curvature when surges above system pressure are encountered, and there is no possibility of metal distortion that would affect switch accuracy. In the low settings the new Barksdale pressure switches will actuate at 0.1" mercury with proof (test) pressure to 10 psi. In higher ranges they will go up to 300 psi proof (test) pressure at settings to 150 psi.

Stripped switch (single and dual control)

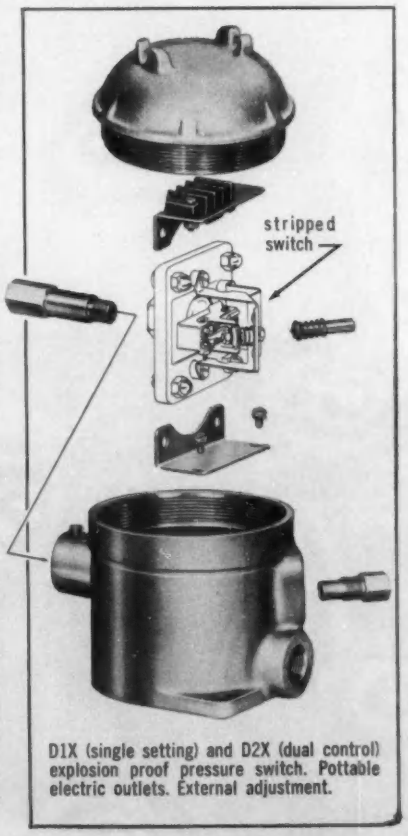
Addition of a switching element (No. 4 above) to the basic diaphragm unit makes a stripped switch for use in a common cabinet with other electrical devices. Original equipment manufacturers need not pay for unneeded housings. Extremely fine adjustment is possible because the adjusting screws have 64 threads to the inch. Adjustment may be made with a screwdriver or a wrench.

Housings added to suit

Addition of a sealed housing (standard, terminal block, or explosion proof) to a stripped switch completes a pressure switch that can be ordered "tailor made" for any desired application. In the standard housing, free wire leads are through a ½" nps conduit conductor. Wires are held firmly in place by a special tension clip that prevents disturbing the switch adjustment through careless wire handling. Terminal block housings are available for wiring convenience. Pottable electric outlets and external adjustment on explosion proof housings were suggested by the petroleum industry. Servicing instructions on all Barksdale switch housing are on the inside of a tamper proof cover to allow for painting of units.

Ask for new catalog

New Barksdale diaphragm pressure switches offer you something new in accuracy, proof (test) pressure, and economy. The just-printed catalog tells the complete story. Ask your Barksdale representative or write to Barksdale Valves, 5125 Alcoa Avenue, Los Angeles 58, California.



D1X (single setting) and D2X (dual control) explosion proof pressure switch. Pottable electric outlets. External adjustment.

Clarence M. Zener

asks what hasn't been asked before



A scientist, says Westinghouse's Clarence M. Zener, has an intense curiosity, which he satisfies by reading and discussion until he hits a problem that can't be solved that way. Then he performs research. "But the biggest contribution a scientist can often make is formulating the problem, asking what hasn't been asked before."

For over 30 years, Zener has been satisfying his curiosity about the structure of materials. As a theoretical physicist, he has asked a lot of questions that have led to an understanding of some of the mysteries of solid state phenomena. And because he is a theorist, not tied to experimental techniques, he has been able to roam across the breadth of solid state physics.

A personality quirk has set Zener hopscotching through a variety of interests. He finds he grows stale if he doesn't change his direction of work regularly. As a result he has moved somewhat more than most scientists.

He earned a B.A. degree majoring in physics at Stanford University in 1926, then started graduate work at Harvard University when the first papers on quantum mechanics were being published. Because the field was new and exciting, Zener did his doctoral research on quantum theory, earning his Ph.D. degree in 1929. The choice turned out to be fortuitous. Without quantum theory solid state studies could not have progressed.

Zener picked solid state for his field of specialization because he thought it might have industrial potential when the depression had almost shut off business interest in physicists. He was forced to go into research, however, as an academic fellow. His first award was a one year Sheldon Traveling Fellowship in Germany. Then he was a Natural Research Fellow at Princeton University, and in 1932 he went to England as a Bristol Fellow.

While he was in England, he developed the theory on breakdown that led to the design of the diode that bears his name. On his return from England he joined Washington University in St. Louis and developed a theory to explain internal friction in solids. Next, he moved to City College of New York to teach physics and to explore ferromagnetism. Zener's efforts were aimed at explaining why material becomes magnetized rather than how. During World War II, at the Watertown Arsenal, physicist Zener developed a theory to explain the mechanism of fracture in metallic parts.

In 1951, he joined Westinghouse's Research Laboratories with a germ of an idea: if one understood the structure of a metal and why it exhibited its properties, one ought to be able to design in any properties desired. From this germ, came a "cookbook" approach to specifying mechanical materials and electrical ones.

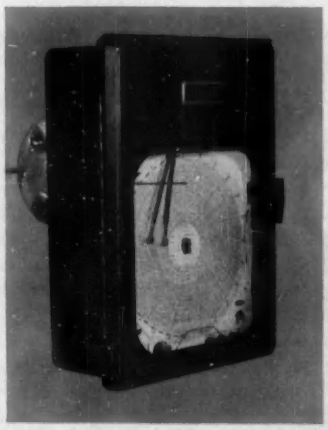
Today, as director of Westinghouse's Research Laboratories, he is still interested in solid state (though right now his personal work is off on a radical tangent: the conversion of sea water to potable drinking fluid, his first effort in engineering). He sees four areas needing work:

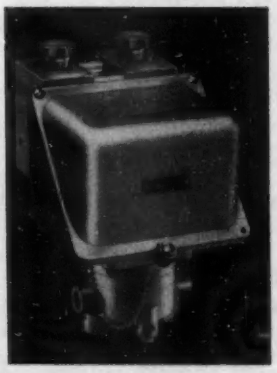
- Most important is learning how to handle many body problems, because physicists have simplified concepts by basing them on a single electron.
- Understanding the mechanism of transition from one energy state to another so physicists can control transition rates.
- Solving problems involving the interaction of the spin of electrons to explain such effects as antimagnetic properties.
- Learning how to build a solid state structure once we have conceived it.

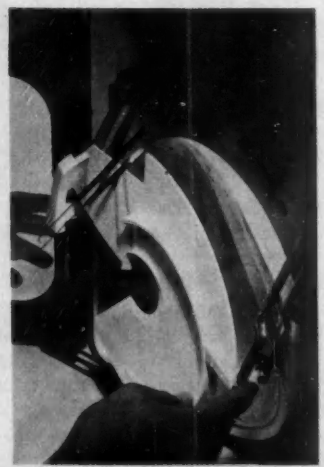
Zener sees the answer to low-cost readily available molecular electronic devices, the one piece system or subsystem. The future of this promising development, he feels, is tied closely to the continued ability of physical scientists to keep asking questions that haven't been asked before.

Exciting things are happening at Barton—new products that answer old problems in the fields of flow, differential pressure and liquid level measurement and control. Examples of these products are: 1) The Model 273 Pneumatic Transmitter which offers ranges from 0-4" w.c. to 400 psi, with safe working pressures to 10,000 psi. 2) The Model 266 Chart Changer, the simplest and most dependable device for automatically changing and storing recorder charts. 3) The Model 269 Wide Range Integrating Flow Meter that accurately measures gas flow over a range as high as 15:1. These are but a few of the important developments taking place at Barton that can benefit your business. Be sure to see them at booth 653.

SEE THESE THREE OUTSTANDING BARTON INSTRUMENTS AT THE ISA SHOW







BARTON
INSTRUMENT CORPORATION
MONTEREY PARK, CALIFORNIA

Newsbreaks In Control

Digital Economic Dispatch Computer On Line

Philadelphia—First digital computer in economic dispatch application went on line last month at Philadelphia Electric Co. Invading a field that has until now been the province of analog computers, the Minneapolis-Honeywell H-290 computer will assign portions of the load to 11 generating stations.

Huntington Beach in Full Operation Without Computer Control

Huntington Beach, Calif.—Unit number four, a 225-000-kw generator, has gone on line here, boosting the capacity of the Huntington Beach Station of Southern California Edison to 870,000 kw. But the computers that were to automatically start up and shut down Units three and four are still not operating on-line. Unit three started operation at the end of 1960. General Electric is supplying two GE 312 control computers (see CtE, May 1961, p. 27).

Molecular Slide Rule

Pittsburgh—At the Westinghouse Research Laboratories, scientists have developed a molecular electronic slide rule. The one-piece semiconductor device can multiply and divide, performing the same way the traditional slide rule would: adding and subtracting logarithms. The new Westinghouse device uses semiconductor junctions. An electric current generates a voltage across the junction proportional to the logarithm of the current.

Replacements for Punched Tape?

San Francisco—At WESCON, visitors were talking about at least two systems being offered to replace punched tape as an input medium in data processing and programmed control applications. Both rely on blackening paper with an electrostatic process instead of punching holes. Major advantage: the new devices can produce punched tape as fast as an optical reader can read it. One major disadvantage of punched tape has been the time required for punching. High speed punches cost at least $10,000. The photographic tape makers are expected to cost around $5,000. Suppliers: Teledynamics Div. of Arma Corp. and Omnitronics Div. of Borg-Warner.

Higher Speeds for Data Transmission

New York—Manufacturers are pushing back the limits on data transmission equipment. Last month, IBM demonstrated its new 1945 tape unit that can simultaneously transmit and receive data at rates up to 62,500 seven-bit characters per sec. Meanwhile in Minneapolis, engineers at Control Data Corp. have successfully transmitted data at rates as high as 1.5 million bits per sec over a microwave link.



13-5

Low Cost Digital Control Computer

A sophisticated low-priced control computer with capabilities ranging from simple logging to closed-loop control, the TRW-330 brings you a new standard in flexibility. You can start with a small basic system that matches your current requirements and then add capabilities as you need them.

Thompson Ramo Wooldridge has successfully installed more digital control computers than any other manufacturer. Because TRW-330 design is based on this experience, you are assured that a TRW-330 system offers the greatest value per dollar in computer hardware – in flexibility, reliability, efficiency.

TRW-330 FLEXIBILITY – Memory sizes range from 4,000 to over 100,000 words; analog input capacity from 0 to over 1,000; an optional subsystem permits automatic scanning and alarm functions to proceed independently of the computer's control program. A similar degree of flexibility is afforded by the TRW-330's analog-output system, priority interrupt circuits, digital input-output equipment, fast-access storage, and command structure.

TRW-330's are supplied in cabinets that match the application: rugged cabinets for harsh industrial environment, air purgable cabinets for hazardous environment, or standard control-room cabinets.

TRW-330 CAPABILITIES – TRW-330 computing speeds exceed those of competitively priced machines; addition instructions can be performed in 260 microseconds, including access time.

TRW Computers Company

a division of ***Thompson Ramo Wooldridge Inc.***

8433 FALLBROOK AVENUE · CANOGA PARK, CALIFORNIA

TO FIND OUT HOW THE TRW-330 CAN BE APPLIED TO YOUR CONTROL PROBLEM, CONTACT ANY OF THE TRW COMPUTERS COMPANY OFFICES LISTED BELOW.

220 North Canon Drive	1510 Esperson Building	200 East 42nd Street	200 South Michigan Avenue	3272 Peachtree Road, N.E.
BEVERLY HILLS, CALIFORNIA	HOUSTON, TEXAS	NEW YORK 17, NEW YORK	CHICAGO, ILLINOIS	ATLANTA 5, GEORGIA



Software, like this deck of cards which is a general program for electric utility customer accounting, can save a user as much as $100,000.

Computer Software—Boon for the User*

Programming packages may be more important than the computer machines to users. Here is the first survey of broad application packages available to computer users.

NEW YORK—"In five years, all manufacturers' computers in the same size range will look pretty much alike. They'll have about the same capabilities of storage and arithmetic speed. The big difference is going to be in software."

That is what a General Electric computer sales manager told CONTROL ENGINEERING last month. Although his opinion could be extreme, evidence to support it is piling up. At RCA, for example, programmer specialists estimate that the average computer user now has invested about $300,000 in software. That means the current software inventory in the U.S. has cost almost $2 billion.

By software, these men mean the programming packages that are available to work with general purpose digital computer hardware. In the past six months, there has been a noticeable rush of activity by computer makers to increase the number of broad programs of possible interest to many different types of users.

Item. Last month, Minneapolis-Honeywell's Electronic Data Processing Division formed an automatic programming group that will have equal status with engineering, manufacturing and marketing divisions.

Item. At RCA's Computer Department, the applied programming group has grown so it occupies most

***What's in a Name?**

The title was selected by the author, but he had help from an RCA 501 computer. With RCA programmers, the author chose some key words as input data and the computer combined them in acronyms using RCA's program TAG. One suggestion the computer offered was to name the story "COSMIC—COmputer Software Management Interests and Control". Another possibility was a poor acronym but a suggestive title: "Automatic Programs Boom Management Control". In all, the machine offered 243 five-word combinations of 15 key words and 81 four-word combinations of 12 key words.

TABLE I—Automatic Programming Systems

Supplier	Name	Description	Machine	Available
Bendix	ALGO	Universal algebraic language compiler	G-15	Now
Bendix	Algebraic Compiler	Universal algebraic language compiler	G-20	1962
Bendix	COBOL 61	Business compiler	G-20	1962
Burroughs	FORTOCOM	Fortran algebraic compiler	B-205	Now
Burroughs	ALGOL 58	International algebraic compiler	B-205, 220	Now
Burroughs	ALGOL 60	International algebraic compiler	B-5000	1962
Burroughs	COBOL 60	Business compiler	B-5000	1962
Control Data	FORTRAN	Fortran language algebraic compiler	1604, 160, 160A	Now Feb. 1962
Control Data	CALINT	Algebraic interpretive program	160	Now
Control Data	COBOL	Business compiler	1604	1962
General Electric	GECOM	General compiler which accepts COBOL, ALGOL, and TABSOL languages	GE 225	Now
IBM	AUTOCODER	General programming	1401, 1410, 705, 7070, 7072, 7074, 7080	Now
IBM	COBOL	Business language	1401, 1410, 705, 7080, 7070, 7072, 7074, 709, 7090	Fall 196 1962
IBM	Commercial Translator	Commercial data processing	705, 7080, 7070, 7072, 7074, 709, 7090	Now
IBM	FORTRAN	Scientific and technical problem programming	1401, 1410, 1620, 650, 704, 709, 7010, 705, 7080, 7070, 7072, 7074	Now
Minneapolis-Honeywell	FACT	Business compiler language made of basic business language	H-800	Now
Minneapolis-Honeywell	Algebraic compiler	Programming scientific problems	H-400, H-800	Now, 1962
Minneapolis-Honeywell	COBOL 61	Business compiler	H-400, H-800	1962
Philco	ALTAC	Fortran compiler for scientific problem solving	S-2000	Now
Philco	COBOL	Business compiler	S-2000	Fall 1961
Philco	JOVIAL	Modification of ALGOL for scientific problem solving	S-2000	1962
RCA	COBOL 60	Business compiler	501	Now
RCA	COBOL 61	Business compiler	601, 301	1962
RCA	ALGOL	Scientific problem solving—offer a FORTRAN subset	601	Now
Remington Rand Univac	Flow-Matic	Business compiler	Univac I, II	Now
Remington Rand Univac	Flexi-Matic	Combined business and scientific compiler	Univac I, II	Now
Remington Rand Univac	Math-Matic	Mathematical problems	Univac I, II	Now
Remington Rand Univac	COBOL	Business compiler	Univac II, III, 490, 1107	Now
Remington Rand Univac	FORTRAN/ALGOL	Scientific problem solving	1107	Now

of one large building, has four separate sections working on software, each concerned with developing a different type of program.

▶ Item. Philco's Computer Department now has over 50 programmers doing research and development on general software, with broad application potential.

▶ Item. IBM has recently set up a systems engineering group whose job is to help tailor large broad programs for specific users.

Although a piece of complex software can cost almost as much to develop as a new computer, all the computer companies give the programming packages to their customers at no cost, or at the cost of the punched cards or magnetic tape that carry the program (see photo, p. 25). In this way, the makers hope to marry the customer to one machine or one product line. Incidentally, the new software tends to increase the use of the machine, running up the number of hours per day a customer runs his machine and, in some cases, has led to the installation of additional computing capability.

• **What's software?**—Computer programs, of course, are not new. A general purpose machine can't run without one since it contains the step-by-step instructions that direct the machine through a problem. Until the current boom in software started, a computer user generally had to write his own with the help of the computer supplier. Some of these took years to complete and cost up to $125,000.

In today's growing software business, computer men talk about four kinds of generalized programs:

▶ **Subroutines**—direct the computer through a variety of important tasks such as making reports (a report generator), sorting or merging information into different categories, running input and output equipment, and performing special mathematical operations such as square root or statistical regression analysis.

▶ **Compilers or automatic programming systems**—software that takes the human programmer's instructions, written in "programming English," and converts them to the special coding of machine language.

▶ **Supervisory operating systems**—programs that optimize the operation of a computer center. They synchronize the start and stop of peripheral equipment automatically and change the operating programs automatically in computers that can work on more than one problem at a time.

▶ **Application programs**—A large sophisticated computer program that can run a machine through a problem common to many businesses, such as scientific article information retrieval, budget control, and sales forecasting.

• **How they fit**—Probably the best known pieces of software to date are the compilers or automatic programming devices. If a machine has such a compiler, the programmer can write his instructions in programming English and the computer will automatically convert it to machine language that can cause the instruction to be performed.

Previously programming was a slow, time consuming operation. After the programmer had atomized his problems into tiny steps that the computer could perform, he had to write one or more instructions for each step. For example, to add two numbers the programmer might have to write these three instructions: *transfer a number from memory block 1080 to the addition register; add a number from memory block 1085; transfer the quantity in the addition register to memory block 1090.*"

Then he would have to convert each of these three instructions to a code number that could be inserted into the machine in binary form to perform the operation. "Transfer from memory" might be represented by 800 which in binary form is 1100100000. "Add from memory" might be 900 And "transfer from addition register to memory" might be 950. Because the coding and the instruction steps vary from machine to machine this procedure is even more unsatisfactory. An instruction coded this way for the IBM 7090, for example, would stall any other make of computer.

• **Languages**—Computer languages have been developed to shorten the instruction writing procedure. And the compiler programs speed up the translation of the instructions to machine language by coding the instruction automatically.

The most common languages in use today are: FORTRAN, ALGOL, and COBOL. They could be called programming English. FORTRAN (Formula Translator) is a language, developed by IBM but also used by other computer manufacturers, that allows a programmer to write instructions to solve engineering, scientific, and mathematic problems almost in the language of the problem. ALGOL (Algebraic-Oriented Language) is also a language for preparing instructions for scientific problem solving, but it was developed by an international committee of computer makers and users. COBOL (Common Business-Oriented Language) is a programming language to write instructions for business data processing programs; it has been developed by the U. S. Defense Department and a committee of computer manufacturers and users called CODASYL. A manufacture takes the language specifications and designs a compiler for his own machine.

Frequently the languages are seen with a number, such as COBOL '60. That means the compiler has been built around the specifications for COBOL language that were published in 1960 (see Table I).

Other languages that are also used: FACT, a language for business data processing developed by Minneapolis-Honeywell; and JOVIAL (Jules' Own Version of the International Algebraic Language) a programming system developed by mathematicians at Systems Development Corp. for scientific problem solving; and IBM's Autocoder for business data processing.

• **A trend**—Automatic programming is developing along two lines, what computer people call *procedure-oriented languages* and *problem-oriented languages*.

In the former the program has to be written in terms of computing rules. For example, in a problem to determine the hypotenuse of a triangle, the programmer would write "*find the third side of a triangle by taking the square root of the sum of* a^2 *plus* b^2".

In a problem-oriented language, the programmer would merely write, "find the third side of the triangle" and leave it to the compiler to find the best mathematical method. To date all the languages announced have been procedure-oriented. The chart on p 28 compares how a simple problem might be programmed in ALTAC (a language developed by Philco), ALGOL, and COBOL.

TABLE II—Application Programs

Supplier	Name	Function	Machine	Available
Bendix	Critical Path Method	Automatic scheduling of multi-variable projects	G-15	Now
Bendix	Linear Programming	Solves three classes of problems	G-15	Now
Burroughs	Operations Research	Solutions of linear programming	220, 205	Now
Control Data	PERT	Automatic scheduling of multi-variable projects	1604	Now
General Electric	CHECPAC	Demand deposit accounting for commercial banks	GE 225 GE 210	End of 1961
General Electric	Critical Path Method	Automatic scheduling of multi-variable projects	GE 225	Now
General Electric	Linear Programming	Generalized program to accept. any problem	GE 225	Now
IBM	Demand Deposit	Complete demand deposit function for banks	1401	Now
IBM	Automobile Rating	Codes passenger cars and delivery vehicles for insurance companies	1401	Now
IBM	Welfare Payroll	Welfare program accounting	1401	Now
IBM	Blue Cross/Blue Shield	Hospitalization plan accounting	1401	Now
IBM	County workshop	Automatic valuation of real property for tax purposes	1401	Now
IBM	SURE	Customer accounting for gas and electric utilities	7074, 7090	Now
IBM	Hospital patient, payroll and inventory accounting	Full hospital accounting	Ramac 305	Now
IBM	MOS	Correlates six basic manufacturing functions	All IBM random access systems	Now
IBM	LESS	Least cost estimating and scheduling	650, 1401 1620, 7070	Now
IBM	Capital Investment	Analyzes profitability of proposed investments	650, 1620	Now
IBM	KWIK-Index	Information Retrieval	704	Now
IBM	AUTOPROMPT	Generates media to run numerically controlled machine tools	704, 709, 7090	Now
IBM	Limited Information Estimation	Forecasts needs of business and industry	704, 709, 7090	Now
IBM	Machine Loading Problem	Allocates products to machines or plants to meet minimum cost and maximum profit	704, 709, 7090	Now
IBM	Taxonomy Application	Compares and classifies great masses of qualitative information for scientific research	704, 709, 7090	Now
IBM	Production Line Balancing	Assigns assembly line jobs for maximum efficiency in completing them	650	Now
IBM	Engineering Requirements	Computes engineering requirements for manufacturing control	709	Now
IBM	Sales Analysis	Performs sales analysis computation	1620	Now
Philco	Linear Programming	General program	S-2000	Now
RCA	Sales Forecasting	Predicts sales volume	501	Now
RCA	PERT	Multiproject scheduling	501	Now
RCA	Human Resources Packages	Catalogs and classifies manpower, prints out "dictionary" of manpower	501	Now
RCA	TAG	Naming program for setting up acronyms	501	Now
RCA	Financial Model	Predicts balance sheet	501	Now

• **Supervisory programs**—Probably the most sophisticated example of a supervisory operating program is the one developed for the Air Force to operate the SAGE system. Upon receipt of information from a warning system, this program starts a flood of input information into the computers.

Few commercial users have problems as complex as Air Defense. But supervisory programs are becoming more important with the use of computers that can work on more than one problem at a time and with satellite computing systems. Today every computer manufacturer either offers a supervisory system or has one in the preparation stage (see Table III, p. 28).

• **Application programs**—The area with the biggest promise for users is the application program that solves a big problem common to many businesses. Such programs can save large sums of money for computer users, can shorten the time required to get a system operating, and can extend the percent utilization of a data processing system. And by solving more problems with the same equipment, these programs ease the economic justification of a data processing system.

Because one company could use an

Rheem

Offers You...

RELIABILITY
ACCURACY

Rheem Electronics Designs and Builds a Full Line of Automation Specialty Accessories, Including...



Economically Priced
PHOTOCELL READERS

■ Reading Rates...20, 100, 300 Lines per Second ■ 5, 7, 8 Punched Tape ■ Silicon Solar Sensing Cells ■ Completely Transistorized Output Amplifiers and Control Circuits ■ No Contacts to Wear Out or Cause Errors Due to Bounce ■ Desk or Rack Mount ■ Tape Handling Equipment



Shaft to Digital
CONVERTERS

■ No Coded Discs...No Contact Pickups ■ Shaft Rotation Sensed by Two Magnetic Heads ■ Phasing Determines Rotation Direction and Magnitudes ■ Low Torque Load

For: Radar Antenna Angular Position Sensing ■ Machine Slide Position Sensing for Position Display Purposes ■ Scale Platform Sensing for Digital Weight Readout ■ Analog to Digital Converters

Write for full information TODAY!

Rheem electronics

Designers and Builders of Complete Numerical Positioning Control Systems

A Division of Rheem Manufacturing Company

9200 West 104th Street, Los Angeles 45, California, SPring 6-1800

WHAT'S NEW

HOW COMPUTER LANGUAGES WORK

Problem: With 50 numbers, add all positive and all negative numbers. (Requires 11 steps in manual programming.)

In ALTAC (Philco's programming language)

```
        Sumpos = 0, Sumneg = 0 $
        Do (end) I = 1, 50 $
        If (Value (I)) LT (0) Sumneg = Sumneg + Value I $
        If (Value (I)) GT (0) Sumpos = Sumpos + Value I $
End     Continue $
```

In ALGOL

```
        Sumpos: = Sumneg: = 0
        Begin For I: = 1 Step 1 Until 50
        Do If Value (I) GT 0 Then Sumpos = Sumpos + Value (I)
          Else If Value (I) LT 0 Then Sumneg = Sumneg + Value (I)
        End
```

In COBOL

```
        Sumpos Equals 0, Sumneg Equals 0,
        Perform ABLE Varying I From 1 To 50 By 1
ABLE    If Value (I) Positive, Then Add Value (I) To
          Sumpos; Otherwise If Negative, Add Value (I)
          To Sumneg.
```

COMPUTER SOFTWARE REPORT (cont.)

application program that IBM developed—SURE, Customer Accounting for the Utility Industries—the user saved about $100,000 and got its system in operation a year sooner.

This IBM program illustrates one broad approach computer manufacturers are taking to application software, solving a very specific problem in a specific industry. IBM, for example, has studied its customer lists and picked some key areas it feels have broad interest. They have pinpointed some specific problems and developed programs to solve them. Examples: student accounting in schools, demand deposit accounting for banks, and hospital payroll. These (and the others listed in Table II) are included in what IBM calls a Programmed Application Library.

To write SURE, IBM programmers worked closely with half a dozen utility companies. It is estimated that the completed package will solve 80 percent of an average utility's customer accounting. Program to handle the remaining 20 percent of activity can be written and woven into SURE.

Quite another approach is illustrated by RCA which has aimed its programs at broad management functions. (IBM too has some management oriented programs.) For example, RCA software planners determined the company balance sheet was a common denominator in every company—every company has one prepared annually, semiannually or even monthly. RCA's program called the Financial Model allows a company officer to see a future balance sheet. If the president, for example, wants to know what doubling sales of a certain product would do to the balance sheet, Financial Model will calculate one, showing how much money would have to be spent for capital expenditures, for additional sales expense, and other varying costs.

Next RCA tackled sales forecasting,

TABLE III—Supervisory Operating Systems

Supplier	Name	Description	Machine	Available
Burroughs	MCP	Master control program	B-5000	1962
Control Data	Automonitor Routine		1604	Now
Control Data	Satellite Automonitor		1604-160 combination	Sept. 1961
IBM	SOS	Master executive program	7090, 709	Now
M-H	Executive System		H-800	Now
Philco	TOPS	Total operating system	S-2000	Fall 1961
Philco	SYSC	Operating system used in conjunction with ALTAC compiler	S-2000	Fall 1961
RCA	Executive Routine		RCA 601	Now
Remington Rand Univac	Executive System		Univac III, 490, 1107	Now

DYSTAC® Iterative Analog Computers Go Operational; Score High in Information Processing and Computation

RECENT INSTALLATIONS

Daystrom, Systems Div. La Jolla, California	2
Humble Oil & Refining Co. Baytown, Texas	1
Marquette University Milwaukee, Wisconsin	1
Case Institute Cleveland, Ohio	1
Texas A & M College Station, Texas	4

More DYSTAC *Iterative Analog Computers will soon be operational at other companies and institutions.*

Recent installations of nine DYSTAC *iterative analog computers have demonstrated the outstanding capability of the analog with a memory... a capability that hurdles the limitations of existing analog and digital computers.*



DYSTAC Iterative Analog Computer

Send For These Reports

Basic DYSTAC *Theory* Report 0012

Correlation and Optimization with DYSTAC Report 0003

Continuous Memory with DYSTAC Report 0004

Counter Current Multi-Stage Oxidation with DYSTAC Report 0006

Radar Antenna Design Studies using DYSTAC Report 0007

Complex Chemical Equilibrium using DYSTAC Report 0008

Bounded Fourier Integrals with DYSTAC Report 0010

Simulation of Transport Delay with DYSTAC Report 0011

Linear Programming on the DYSTAC *Computer* Report 0013

New Solutions in the Science of Simulation Report FB

High Speed Memory Analog Computer Report IEC3610

Low Cost Speed for Information Processing Report CE7610

Nonlinear Programming Technique For Analog Computation Report CEP6610

Memory Permits Use of Numerical Techniques

Because of its memory feature, the DYSTAC computer can follow iterative procedures by automatic transfer of stored results from one iteration to the next. Because each iteration is very fast, this computer retains the speed advantages of the conventional analog, yet eliminates equipment size limitations of conventional analog procedures. Memory also permits time sharing of computer elements.

What DYSTAC Computers Can Do For You

- —DYSTAC solves problems in fraction of gross time required by digital computers with a fraction of equipment required by any other analog computer.
- —DYSTAC solves problems hitherto unsolvable by computer techniques.
- —DYSTAC solves problems at multi-speeds simultaneously.
- —DYSTAC offers high-accuracy prediction for real time control.
- —DYSTAC offers true max-min capabilities for process model development, optimizing operating conditions, and on-line optimizing control of several operations with one computer.
- —DYSTAC is your economical answer to high speed computation of multiple integrals and partial differential equations, definite integrals, multi-dimensional partial differentials, etc.

COMPUTER SYSTEMS, INC. Culver Road, Monmouth Junction, N. J. • DAvis 9-2351

A Schlumberger Subsidiary

Computer engineers with analog and digital backgrounds, who wish to explore the many professional opportunities available, are invited to send resumes.



WHAT'S NEW

produced a program that allows a sales manager to improve the accuracy of his forecasts. At RCA's own television department, the program improved forecasting accuracy by reducing the difference between predicted and actual annual sales from five percent without the computer to one percent.

RCA also offers a program to catalog a company's manpower resources. If the personnel department inputs resume information in English, the computer program will tally the number of times each word is used and a search can be instituted for any classification. For example, such information as this can be typed in on a Flexowriter:

John Jones; Control Engineer; Five Years Experience in Process Control; Two Years Computer Programming; Good Sales Personality; EE, Stanford; MBA, Harvard.

The program would find John Jones' record if a search were instituted to locate "control engineers", or "engineers with computer programming experience", or "Harvard Graduates", or any other word combination that would fit Jones' experience. In addition, the program will print out a "dictionary of manpower" indexed any way an executive might ask.

• **The rush is on**—Almost every company has announced or has in preparation a version of PERT (Program Evaluation and Review Technique) or Critical Path Method, management techniques for evaluating how projects are meeting schedules.

In addition to these business programs, all manufacturers have a variety of specific engineering problem solving programs. For example, Burroughs is very strong in X-ray analysis; and IBM has a strong library of civil engineering programs.

All computer manufacturers operate library services that share specific programs developed by their customers as well as their own programmers.

Just how fast the software business is growing can be seen by what's happening to the IBM Library Services Dept, which merely distributes programs. Last December, it occupied about 5,000 square feet of space and filed about 2,000 programs and subroutines. Today, it occupies almost 15,000 square feet of space and its files bulge with 5,000 items of software. By January 1963, librarians will have moved to two floors in IBM's White Plains location, will have over 8,000 programs on file, and will be using their own computer to keep track of requests.

Lewis H. Young

Electronic Medicine Meetings Host to 3,000 Engineers, MD's

Industry seers who view medical electronics as a bright outlet for electronic control techniques were cheered by big attendance, number of papers, and show activity at joint conferences held in July.

NEW YORK—Six years ago, when the field of medical electronics was just becoming recognized, a national conference was held in New York to hear 20 papers on fledgling efforts. The fourth such meeting was held here in July; now the sessions have grown to the International Conference on Medical Electronics. Combined for the first time with the Annual Conference on Electronic Techniques in Medicine and Biology, the joint confab played host to 3,000 engineers and medical men who heard 299 papers. Seventy companies exhibiting in the accompanying show tried at the same time to make some dollar sense out of a group that is known for its tight pocketbooks.

Many of the techniques described in the technical sessions and demonstrated in the exhibit booths were borrowed from industrial or military control techniques. Instrumentation, telemetry, and information systems—tools familiar to the control field—are now being applied to medicine.

• **Checking the patient**—Many papers dealt with what doctors feel is the first step in medical automation: measuring the patient's condition and converting his symptoms into an electrical signal.

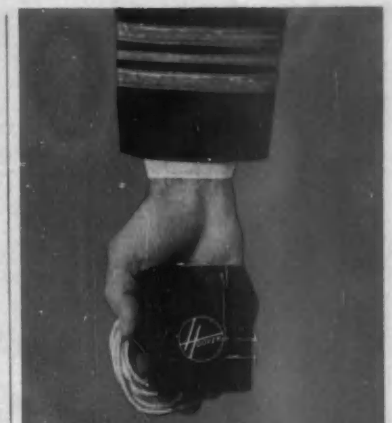
With many hospitals using subprofessional personnel (nurse's aides, volunteers) for blood pressure checks, there has been a need for equipment that allows unskilled operators to measure blood pressure with high accuracy. The automatic machine described by L. L. Edinger and M. Spring of the East Bronx Medical Group can measure systolic and diastolic blood pressure with greater accuracy than the standard sphygmomanometer, and the machine is easy to use. Output signals from a pulse pickup secured to the patient's arm by an inflatable sleeve are amplified to trigger a pair of multivibrators. One multivibrator operates an electromagnet that arrests the diastolic pressure gage as soon as one pulse beat is not followed by another within 2 sec. The other arrests the systolic gage when the first beat occurs during sleeve deflation.

The difficulty of accurately measuring blood flow in unopened arteries may be eased by a nuclear technique devised at the Biomechanics Research Center at Wayne State University by A. I. King, D. Lindner, E. S. Gurdjian, and H. R. Lissner. They have injected radioactive isotopes into the bloodstream and aimed a gamma ray collimator at two points 2⅜ in. apart. As the isotope passes, gamma rays are focused on a single scintillation crystal. Output pulses are read into a recorder, the pulses are plotted against time, and the distance between sharp slope changes gives average blood velocity to within 4 per cent.

An automatic approach to measuring the heart condition of a patient was described by B. H. Dennison of Melpar, Inc. His Cardiac Sentry turns a standard electrocardiograph (EKG) recorder into a continuous heart monitor. The output of the EKG recording galvonometer is filtered, amplified, rectified, stretched, and inverted to get negative pulses that are compared with predetermined safe limits. If the patient's heart parameters exceed the limits, an alarm light and a remote audio alarm come on. A 15-sec EKG record is then taken, and prescribed medication can be initiated and controlled automatically or a cardiac stimulator can be turned on.

• **EKG on the go**—Another problem that aerospace telemetry seems now to have under control is the taking of EKG data from a moving patient. Cardiologists have long suspected that they could tell more about the condition of a patient's heart if they could make an electrocardiograph while he was moving. This chart, combined with an EKG taken in the standard, resting position, would enable the doctor to discover whether the patient developed dangerous heart symptoms only while exercising. There have been cases of patients being felled by coronary attacks shortly after leaving a doctor's office where a perfectly normal EKG had been taken.

Bernard Schwartz of Telemedics, Inc. described his company's RKG 100, which uses techniques developed for astronaut training. To take an electrocardiograph using the RKG



This versatile power converter (Model DPC-113), is a symbol as well as a significant improvement in conversion efficiency. It stands for Hoover's "capabilities in reserve," for the broad range of products and creative abilities found in Hoover's *industrial* spectrum, grown out of Hoover's long-noted work in military applications.



Model DPC-113 is ideally suited for applications whose power source is a thermoelectric generator, fuel cell, low voltage battery . . . for battery charging equipment in radio and radar beacons, signal buoys at sea, space platforms, microwave link stations, vehicle-mounted equipment, standby power sources in general. With it, applications once regarded as impracticable now become practical.

With its efficiency (greater than 75%), a wide range of input and output parameters is available. Solid state construction eliminates maintenance problems.

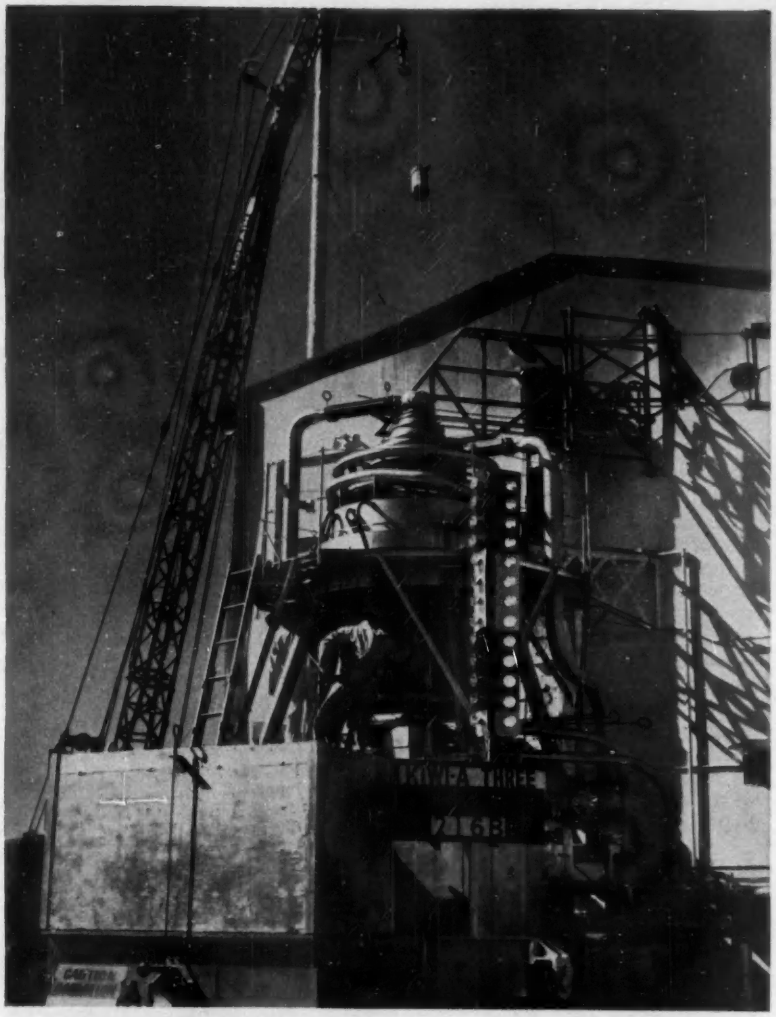
Inputs as low as 0.1 volt are practical, and virtually any output, ac or dc, can be supplied. Fully encapsulated, it can even live under sea water indefinitely.

For further information, write you address J. C. Miller

THE HOOVER COMPANY
ELECTRONICS DIVISION

$$R_s = \prod_{i=1}^{n} r_i$$

CIRCLE 31 ON READER SERVICE CARD



KIWI-A THREE... the third successful nuclear rocket propulsion reactor developed by Los Alamos Scientific Laboratory for Project Rover. Testing of new designs is continuing at an accelerated pace.

Opportunities exist for engineers and scientists who have had experience in the following areas: automatic controls systems, computer simulation, electronic aspects of controls systems, reactor design and operation, fluid flow control, and cryogenics.

For employment information send resume to:
Personnel Director, Division 61-54R

los alamos
scientific laboratory
OF THE UNIVERSITY OF CALIFORNIA
LOS ALAMOS, NEW MEXICO

32 CIRCLE 32 ON READER SERVICE CARD

WHAT'S NEW

. . . monitoring systems watch over many patients, reporting key health parameters . . .

100, the doctor attaches two electrodes to the patient using adhesive spot bandages. These are wire connected to a pocket-sized, 10-oz FM transmitter. The patient then carries the transmitter through any series of simulated or normal daily activities. EKG signals are transmitted—over distances of upwards of 500 ft—to the RKG 100's main unit. Signals are fed from this table-top device to a separate EKG recorder or oscilloscope.

Telemedics sold 10 of the devices (priced at $2,100) in two months.

• **Getting the data**—As the shortage of nurses worsens, hospitals are seeking a method of monitoring patients' conditions centrally. One such method, described by E. B. Johnson of ITT Communications Systems, Inc., is a remote monitoring system that can watch up to 12 patients at a time. The patients are each connected to the system's console through a universal chest transducer cluster. Blood pressure is sensed by a sphygmomanometer method, EKG by two electrical leads, temperature by a thermistor, skin resistance by two more leads, respiration rate by strain gages, and breath sounds by a microphone.

The major disadvantages of this system are like those of other central monitoring approaches: a number of leads have to be attached—probably uncomfortably—to the patient. At the equipment show, Minneapolis-Honeywell's Heiland Div. showed a body function recorder that solved this problem, at least for a few functions.

The Honeywell technique uses a headpiece containing three transducers. One, an airflow detector about the size of a silver dollar, is positioned in front of the mouth and nose. Temperature is detected by a small sensor in the corner of the mouth. Then a "clothespin" type of blood pressure and pulse transducer slips lightly over the upper part of the patient's ear. It shines light to a photocell through the tiny blood vessels in the ear. Gentle pressure is applied to the ear so that changes in light intensity signal diastolic and systolic pressure. Pulse is picked up by counting the beat variations in light hitting the photocell.

Medical researchers often have great quantities of response data to handle. Some special data processing techniques have been developed to speed data handling. One researcher proposed a system for alleviating the med-



DESIGNER'S CHOICE

for temperature control– the application-oriented Fenwal "500" Series

A complete line of temperature controls

No two control problems are identical — but solution to any one is simplified by the broad line of Fenwal "500" Series controls. Whether you need an on-off control, or a multi-point proportioning indicator/controller, a standard, stock Fenwal "500" is best for you. We call them application-oriented. Why? Because they combine characteristics that meet and solve the problems most commonly encountered in designing any system requiring temperature control or indication — or control *and* indication. Here are some major problems and the positive Fenwal "500" answers.

Universal Mounting. "500's" mount in *any* position — and controls and indicators function perfectly regardless of the position.

Vibration Resistance. You can shake and shock any "500" control — it's ruggedly built to withstand vibration and shock.

Fast Sensor Response. Thermistor sensing in all Fenwal "500" controls provides the fastest response to temperature variation. And all Fenwal "500" *Indicating Controls* are used with *matched thermistor* probes eliminating calibration.

Extreme Sensitivity. 0.1°F sensitivity — standard for all "500" controls — cannot be topped even by more expensive controls.

the FENWAL

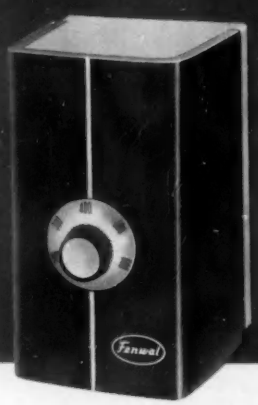


535
5-ampere ON-OFF controller.

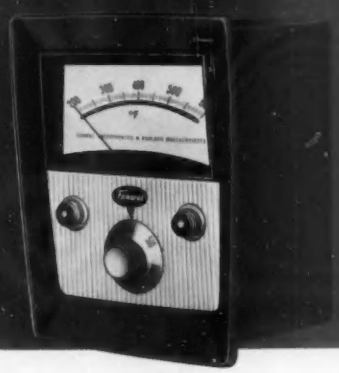


560
Laboratory indicating controller with ON-OFF, proportioning and adjustable differential control.

536
10-ampere ON-OFF or proportioning control. Use separately or with "580" indicators.



561
Electronic indicating controller—ON-OFF or proportioning.



designed for use . . . and abuse

Independent Control Circuit Design. Circuits for control and indication work independently — malfunctions of indication do not affect set point.

Dependability. All-transistor circuits take a beating, also run longer on less power than vacuum tubes. And all "500" units are built for easy servicing.

Precise Readability. "500" indicators are available in a choice of scale ranges from −50 to 1200°F for the accuracy you need in readings. Suppressed zero is standard (and expanded scales can be obtained at extra cost).

Economy. Fenwal "500" controls cost less per unit than comparable controls and offer even greater savings in quantities.

Advanced Styling. The modern yet functional design of Fenwal "500" controls complements the advanced design of any system — and the distinctive techniques of its designer.

By contacting your Fenwal Sales Engineer in the early phases of a design you can get full details and the benefit of his experience in selecting the "500" unit that is compatible with your best design approach. For descriptive literature on any "500" control, write FENWAL INCORPORATED, 299 Pleasant Street, Ashland, Massachusetts.

"500" LINE



582
Multi-point indicator.



580
Multi-point indicator. Use with from 2 to 16 "536" controls.



583
Battery operated portable indicator.

Probes. Fenwal thermistor probes are available in a choice of temperature ranges, mounting styles, sensor configurations. All models can be used with "500" series instruments.



CONTACT YOUR
LOCAL FENWAL REPRESENTATIVE:

ALBANY
Tel: HObart 2-5364

ATLANTA
Tel: TRinity 5-7244

BALTIMORE
Tel: VAlley 5-4445

BLOOMFIELD (N. J.)
Tel: EDison 8-6900

BUFFALO
Tel: TR 6-3757

CHARLOTTE
Tel: 847-1616

CHICAGO
Tel: HArrison 7-5464

CINCINNATI
Tel: TRinity 1-0605
& 1-0606

CLEARWATER (Fla.)
Tel: CLearwater 3-7706

CLEVELAND
Tel: PRospect 1-7112

COLUMBUS
Tel: AMherst 7-8260

DALLAS
Tel: EMerson 8-2325

DAVENPORT
Tel: 6-5233

DENVER
Tel: GLendale 5-3651
GEnesee 3-0821

DETROIT
Tel: KEnwood 8-2100
ELgin 7-0677

FRAMINGHAM (Mass.)
Tel: TRinity 2-3526

HOUSTON
Tel: UNderwood 9-3306

INDIANAPOLIS
Tel: MElrose 5-5313

KANSAS CITY (Mo.)
Tel: SOuth 1-6545

LITTLE ROCK
Tel: FRanklin 4-8825

LOS ANGELES
Tel: DUnkirk 8-3168

MILWAUKEE
Tel: BRoadway 1-3021

MINNEAPOLIS
Tel: FEderal 6-6631

NEW HAVEN
Tel: ATwater 8-1638

NEW ORLEANS
Tel: EVergreen 2392

NEW YORK CITY
Tel: WOrth 4-2990

PHILADELPHIA
Tel: GReenwood 3-4477

PITTSBURGH
(Wilkinsburg)
Tel: FRemont 1-6220

ST. LOUIS
Tel: CHestnut 1-2433

SAN FRANCISCO
Tel: YUkon 2-3713

SEATTLE
Tel: EAst 3-8545

SYRACUSE
Tel: GRanite 1-3074

TULSA
Tel: TE 6-2501

MONTREAL, P.Q.
Tel: WEllington 7-3521

TORONTO, Ontario
Tel: HUdson 3-2776

The application-oriented "500" controls are typical examples of how

Fenwal

CONTROLS TEMPERATURE . . . PRECISELY

Fenwal Incorporated • Ashland, Mass.

MC - 208 9.1.34 Printed in U.S.A. 8/61

WHAT'S NEW

. . . new uses for the computer for experiment, diagnosis, and medical record keeping . . .

ication instruction paperwork.

• **Mechanized pillbox**—Bearing the frightening name HIPO, the system proposed by M. S. Blumberg of Stanford Research Institute would replace present manual systems in hospitals for handling doctor's orders. Blumberg claimed that 5 percent of a hospital's budget is spent on manual order recording setups.

His Hospital Indicator for Physician Orders would be centrally located in the hospital and connected to each nursing station. Order cards would be prepared by the doctor at the station where he would check off the needed drug and schedule and have the patient's code number punched in.

Blumberg suggested that single doses of drugs could be stocked in a dispenser at each station. The dispenser could be keyed to flash an indicator when a dose was due and could then deliver a scheduled medication labeled with the patient's name.

A magnetic drum average response computer was described by Michael Tobin of the Dept. of Psychiatry at the State University of New York. Tobin explained that the electrical response to external stimuli in neurophysiological studies is often obscurred by spontaneous potentials. He has developed a simple method of emphasizing the desired signals and computing their average.

A point on a rotating drum initiates the stimulus to the subject. Response data are fed to a narrow magnetic reading head that is held in contact with the drum and advanced axially by a synchronous leadscrew. Response is thus aligned on spiral magnetic tracks. Readout is by a fixed magnetic head, as wide as the drum is long and parallel with its axis. The summation thus evolved emphasizes the evoked potentials, since they are time-locked to the drum and the background noise is not.

• **"What ails me?"**—Much of the session devoted to computer diagnoses centered around the statistical problems of this approach rather than the hardware to do the job. One of the intriguing ideas for these special purpose computers, however, was a matching computer proposed by V. K. Zworykin of the Rockefeller Institute for Medical Research.

Characteristics of each disease are recorded on film strips as a spectrum

NOW, AVAILABLE **FAST**

FROM 12 NATIONWIDE STOCKING POINTS



TRINITY THERMOWELLS

The Industry's Most Complete Line

Only TRINITY, the industry's leading manufacturers of thermowells, has the facilities and sales volume to institute such a dynamic service designed to fill *your emergency needs* from a nationwide network of twelve stocking points.

NOW, your TRINITY representative can deliver standard thermowells *at factory prices* from Baton Rouge, Chicago, Cleveland, Houston, Los Angeles, New York City, Omaha, S. Charleston, Tulsa, and Toronto and Calgary in Canada.

NOW, you can rely on TRINITY's central inventory at Cortland, New York. Already, it includes many hundreds of ready-to-ship well types stocked in depth, and it is still growing. So even for unusual requirements, you can be sure of same-day shipment you often need.

TRINITY

COUNT ON THE NEW W&T SERIES 100 PUMP WHEN YOU NEED...



...ACCURATE METERING WITH SMOOTH CONTROL

Wallace & Tiernan's newest plunger pump delivers 3.2 gph vs 1200 psi to 50 gph vs 100 psi, repeatable within ± 1%. Easy adjustment over 10:1 range with the pump running.

...DOUBLE CAPACITY OR TWO-LIQUID METERING

A second liquid end doubles capacity or gives simultaneous feeding of two liquids. Stroke length for each end individually adjusted.

...DEPENDABLE, TROUBLE-FREE METERING

Unitized construction means the Series 100 Pump stays in perfect alignment. Wear and maintenance are held to a minimum. Corrosion-resistant wetted parts handle most chemicals. The Series 100 Pump, with motor, is compact. With two liquid ends it occupies less than 2 sq. ft.

For more information write Dept. L-8.28

WALLACE & TIERNAN INC.

25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

of transparent lines on an opaque background. The lines vary in density according to the significance of each symptom. When these films are compared, one by one, with a similar strip representing the patient's symptoms, the light passing through matched lines is a measure of correlation.

• **Muscling in**—One of the most intriguing of the conference papers involved not control applied to medicine, but just the reverse. Two Litton Systems, Inc. researchers, Dr. David O. Ellis and Frank Schneidermeyer, described their investigation of muscle action (electromyographic or EMG) potentials.

When muscles are flexed, spike shaped potentials are developed. There is no activity when muscles are at rest or are gently, passively stretched. These EMG signals, the Litton men have found, can be used as input to an open-loop control system. Properly shaped and amplified, the muscle signals drove a stepping motor.

The next step would be to modify the setup to get a feedback loop. Possible applications: aerospace vehicle controls where high acceleration limits movement but not muscle flexing, artificial limbs and organs, remotely controlled robot arms, and integration with future digital bionic machines.

Many of the techniques described in the papers and shown on the exhibit floor are long in coming to the medical field. But the needed cooperation between the MD's and the engineers now seems to have been established. The future benefits in saving lives can stagger the imagination. Here's an example of what one relatively simple $750 device can do.

The Decker Corp. exhibited an opthalmic artery pulsensor, which gages blood pressure in the opthalmic artery. As Robert Greenberg, Decker project engineer, told CtE, "You never hear of anyone dying of high blood pressure of the arm, but that's where blood pressure is usually measured."

"What you need, sometimes, is the blood pressure near the base of the brain; cerebral vascular diseases caused 12 percent of the deaths in the U.S. each year," Greenberg explained. Formerly this could be done only by a delicate procedure that had to be administered by a doctor.

The Decker device mounts a pressurized cup over the eye. A sensitive transducer senses the pulses induced by the opthalmic artery. The pressure, measured on a manometer, at which these pulses stop is the systolic.

Russians Vary Color and Sound in Man-Machine Studies

LONDON—

Human response is intensified or attenuated under certain combinations of sound and color. That is the conclusion of physiological and psychological studies conducted by Russian experimenters. These scientists believe that changes in the tone, brightness, and intensity of color can affect a human's perception of sound.

To quantify this effect, other scientists at Moscow's Institute of Automatics and Telemechanics have built analog computer equipment that presents both sound and color stimuli to a human subject, then measures the subject's response time and stimuli threshold levels.

At the Soviet Exhibition held in London this past summer, the equipment was shown to the Western World for the first time. At the show, the analog computers analyzed stereophonic music and transposed it into color patterns that were displayed as the music was played.

Every one-tenth of a second, the music was examined to measure four basic parameters that determined the color to be projected. The first parameter is the integrated value of intensity determined over ten seconds —the control signal for intensity.

The second parameter is related to instantaneous energy distribution. Passive filters divide the 30-10,000 cps frequency spectrum into six sidebands. Measuring circuits determine the instantaneous energy distribution.

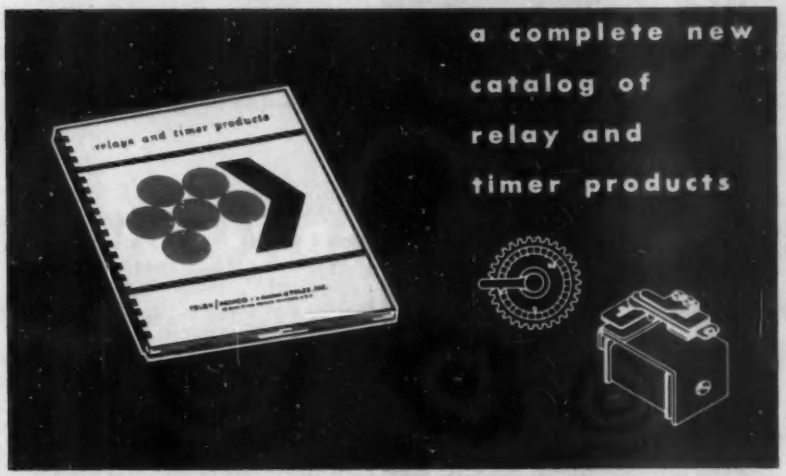
From capacitor stores, which are scanned every ten seconds, come control signals that are proportional to the time variation of the energy distribution in the spectrum—the third parameter. And the fourth is a signal from other capacitor stores related to the change of volume with time.

The four analyzer output signals feed into the first of two analog computers. It solves three equations derived from the theoretical laws coordinating human senses of hearing and sight. Output of this computer is a signal corresponding to the demanded color and its intensity.

How intense each of three primary colors should be is determined by the second computer. The system uses red, blue, and green to obtain all intermediate shades.

—Derek Barlow

Now from TELEX/AEMCO



TELEX/AEMCO
a division of Telex, Inc.
Mankato, Minnesota, U.S.A.

TELEX/AEMCO

presents this new complete catalog of electro-magnetic relay and motor-driven timer products.

Request your free copy on your letterhead or send coupon today.

MAIL COUPON TODAY

TELEX/AEMCO
20 State Street
Mankato, Minnesota

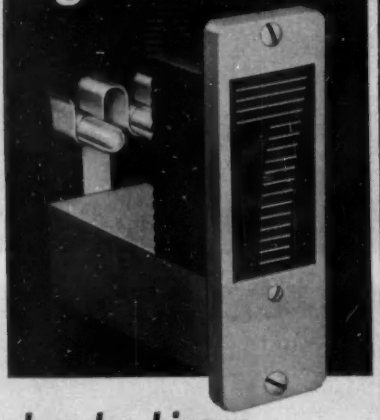
Name_____
Company_____
Address_____
City_____ State_____

a division of Telex, Inc.

CIRCLE 39 ON READER SERVICE CARD

low-cost, binary operated

digital readout



decodes binary... displays alpha-numeric -electro-mechanically

This is the smallest digital readout on the market. It decodes binary information directly, and displays it in any of 16 alpha-numeric characters. Unit accepts voltage signals from digital computers and similar equipment.

Easy-to-read—characters are ¾" x 1½".

Rapid, reliable display—30 characters per second.

Built-in memory keeps last character in position with no power requirement.

Miniature size—mounts in 1" x 3.2" panel. Extends only 2.5" behind panel. Weight: 74 grams.

Low cost—complete, only **$50.00**

Available as DECIMAL-ACCUMULATOR COUNTER—same size and configuration as readout. Displays 0 through 9.

Price **$20.00**

Write for complete data.

data Scope CORPORATION

10125 West Washington Blvd., Culver City, Calif.

Westinghouse Organizes Big Push in Computer Control

New Industry Systems Dept. will spearhead Westinghouse's marketing of computer control systems. Some new ideas are likely to change the face of this electrical manufacturer.

PITTSBURGH—

At Westinghouse's biggest and oldest facility, the East Pittsburgh Works, a modern systems engineering organization is taking shape close to the shops where George Westinghouse built the first alternating current motors. The new Industry Systems Dept. will build on the company's past experience with electric power systems, moving into complex control systems for the steel, petroleum, paper, and chemical industries. And it is likely to lead the big electrical manufacturer into new product lines, such as process instrumentation.

Headed by Paul R. Sprowl, the new group will centralize Westinghouse's know-how in control application engineering. Previously Westinghouse had groups called "Industry Engineering" to do application engineering, pulling together products the company made into systems. Each concentrated on one industry like steel, paper, or electric utilities so there was no chance to share technology that might be used in common.

The specialization slowed Westinghouse down and the company had trouble keeping up with the rapid technological changes in the control field. The dependence on products in the company's line reduced the operational flexibility of these application engineering groups.

Computer control crystallized the problem. It demanded new technological tools and strained the industry organization because it needed equipment the company did not make.

Sprowl's new organization will not only apply Westinghouse products but will buy components from others. Unlike the industry organization, the new group will be customer oriented.

•**The organization**—To date Sprowl's objective has been to set up an organization to complement what other Westinghouse divisions are doing. The new group has established four sections. Showing the company's serious intent in computer control, the first is called Computer Systems. Its manager is R. W. Ferguson, a simulation and control system analysis specialist. The second group is the Process Control Section, which will study the application of process instruments, buying where necessary and developing new devices when they are not commercially available. Its manager is J. T. Carlton.

These groups will centralize process instrumentation, computer programming, and systems analysis, rather than concentrating on an industry or customer.

R. L. Tremaine has been named Project Manager of Industry Systems and will head a group of project engineers, each of whom will be responsible for a major control system for a specific customer.

The fourth group is a marketing organization headed by M. W. Brittain as marketing manager. Westing-

PRODAC, control computer which will be the core of Westinghouse's new Industry Systems Dept., undergoes a preshipment scrutiny.



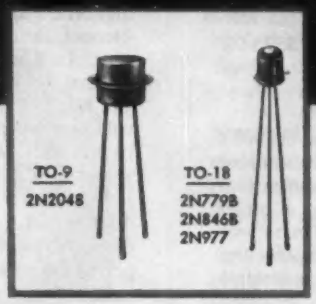
1 to 5 mc COMPUTERS

3 to 20 mc COMPUTERS

10 to 100 mc COMPUTERS

For a 1mc or 100mc-clock Computer

THERE'S A PHILCO 150 mw MADT*®



Seven important circuit advantages, inherent in every Philco MADT, are:

1. **Tight Parameter Control;**
2. **Charge-Control Specification;**
3. **Exceedingly Low V (SAT);**
4. **Very Low Collector Capacitance;**
5. **Freedom from Latching;**
6. **Excellent Temperature Stability;**
7. **Industry's Best-Documented Reliability.**

Four new Philco 150 mw *Micro-Alloy Diffused-base Transistors bring even more versatility to industry's most reliable transistor line. Now, you can benefit from MADT proven product advantages in a broader-than-ever range of applications, including those that require high power dissipation. In addition to an expanding line of 150 mw types, there's the *new ultra-high-speed 100 mw MADT type 2N976—the world's fastest switch.* There's an MADT that gives you optimum cost efficiency for your specific requirements.

For complete information on these high power dissipation MADT's, and application assistance on any transistor circuit, write Dept. CE961.

Philco 150 mw MADT's are immediately available in quantities 1-999 from your Philco Industrial Semiconductor Distributor

PHILCO

Famous for Quality the World Over

LANSDALE DIVISION, LANSDALE, PENNSYLVANIA

SOLID-STATE CENTER U.S.A.

CIRCLE 41 ON READER SERVICE CARD

•MACHINING AND PROCESS CONTROL

•COUNTING

•BATCHING

•SORTING

•MIXING

NEW!

HIGH-SPEED, SOLID-STATE, PRESET COUNTER



MODEL 300T-4S
$575.00

•WINDING

•PACKAGING

. . . or any other physical process that can be electrically digitized.

The completely transistorized Model 300T industrial counter is rugged, dependable and low-cost control instrumentation that is ideal for every use requiring a preset counting device. Modular design minimizes maintenance time and steel construction permits mounting directly on controlled machine. Modules can be easily modified for special applications. The 300T is a truly remarkable instrument that deserves your serious consideration.

Send today for complete technical information.

SPECIFICATIONS

Speed: 6,000,000 counts per minute
Range: 1 to 9,999 standard. 5 to 8 decades available
Reset: Automatic, manual, local or external
Size: 3½" high; 9½" wide; 14" deep (standard model)
Weight: Approx. 10 lbs.

Quality Where It Counts

ERIE Instrumentation.

ERIE PACIFIC DIVISION • ERIE RESISTOR CORPORATION
12932 S. Weber Way, Hawthorne, California
Phone: ORegon 8-5418

WHAT'S NEW

house will continue to rely on its industry salesmen for leads to complex control system jobs. Then Brittain's group, specially trained in computer control technology, will back up the field salesmen.

• **Value added**—To make buying outside the company easier, Westinghouse has introduced a new criteria to judge the performance of Sprowl's Industry Systems Dept. Company executives will study "Value Added" figures instead of totaling up the amount of the company's products sold. The value added concept will give Industry Systems credit for the application engineering that's undertaken, for the systems analysis, and for computer programming—all part of the price of a complex control system.

Many other divisions will be watching how the Value Added concept works in Industry Systems. If it succeeds, Westinghouse may adopt it across the company.

• **For the present**—Until Sprowl's organization reaches full size, it will concentrate in two areas that Westinghouse's Industry Sales has already successfully invaded with computer control. The company has sold two systems to electric utility companies and five to steel mills. Sprowl's group will pick up these jobs and continue to concentrate on the electric utility and steel industries.

But as soon as it can, the group will branch out. The paper industry is likely to be the first addition, then petroleum and chemical companies.

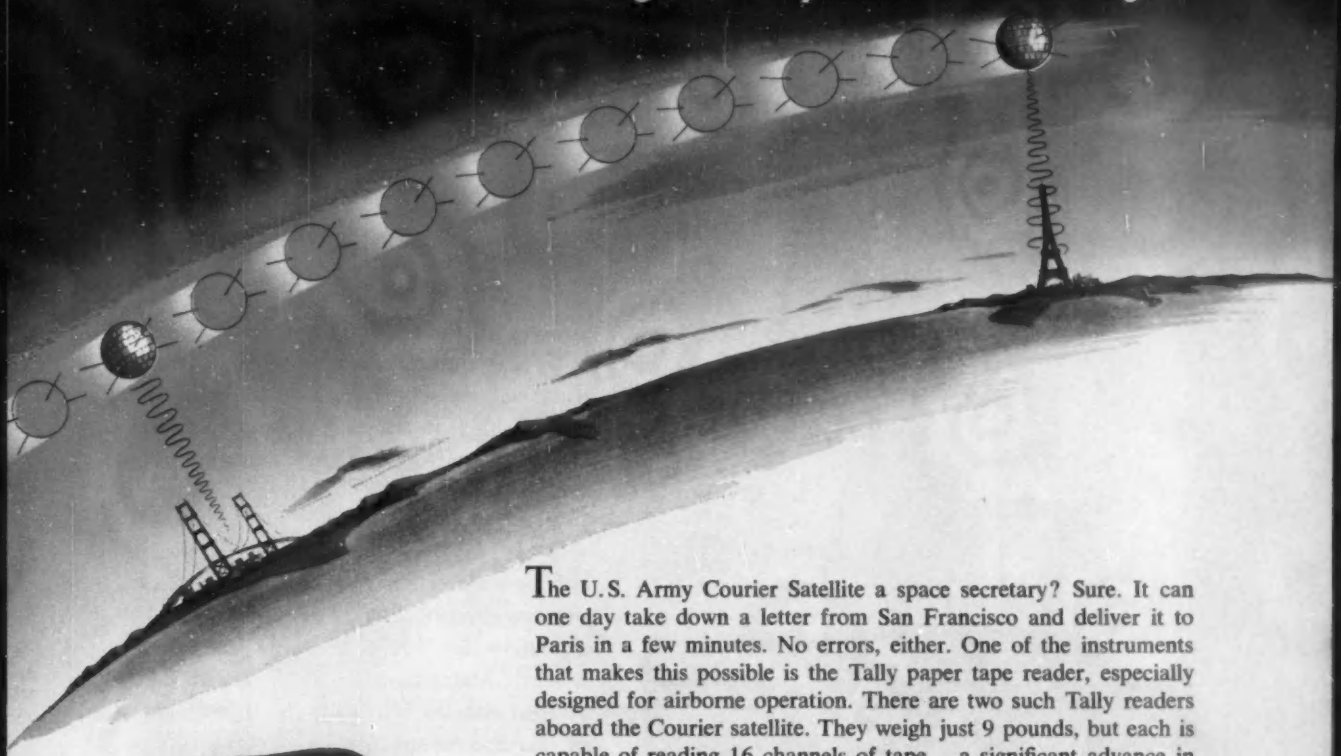
For the time being, Sprowl feels Westinghouse will not develop a line of process control unless a job calls for a device that isn't commercially available. The only manufacturing facility the group has is a model shop to build prototypes. The PRODAC computer, which will be the heart of most of Industry Systems jobs, will still be built at the Buffalo Div.

When the Industry Systems Dept. proves itself, experts are predicting Westinghouse will develop its own line of process control equipment. They point out that Westinghouse seriously considered such a step as recently as 1957, going so far as to study how such equipment should be made to fail safe, but gave up the whole idea in the recession of 1958.

Manager Sprowl is putting no limits on his group. He says it was set up to keep pace with technological changes. The group will do anything it must to keep Westinghouse competitive in computer control.

More business news on page 226

TALLY readers fly in "Space Secretary"



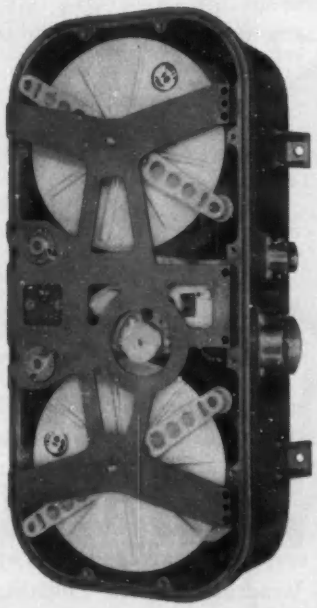
The U.S. Army Courier Satellite a space secretary? Sure. It can one day take down a letter from San Francisco and deliver it to Paris in a few minutes. No errors, either. One of the instruments that makes this possible is the Tally paper tape reader, especially designed for airborne operation. There are two such Tally readers aboard the Courier satellite. They weigh just 9 pounds, but each is capable of reading 16 channels of tape... a significant advance in the state of this particular art.

The satellite readers were built by Tally for the Western Development Laboratories of Philco Corporation, which designed and built the satellite for the U.S. Army Signal Research and Development Laboratory at Fort Monmouth, N.J.

According to Philco engineers, the simple design and reliable operation of Tally readers led to their selection for the Courier Project.

You will find the same simplicity and reliability in Tally's standard, earthbound readers. In fact, they're used in ground stations transmitting and receiving Courier messages.

Write for our tape reader literature. In the meantime, here are some interesting specs on the Courier readers to whet your appetite:



Semi-exposed view of Courier Satellite spaceborne 16-channel tape reader used in Project Courier Satellite, developed by Tally Register Corporation.

ENVIRONMENTAL

VIBRATION (NON-OPERATE) 5 cps at 2 grms to 2000 cps at 10 grms with .4 inch double amp max. (OPERATIVE) To 1000 cps at 3 g's. TEMPERATURE —40° F to +130° F. ALTITUDE 200,000 ft. or better. HUMIDITY At 95% RH 130° F. ACCELERATION 15 g's one axis 4 g's two axis.

GENERAL

WEIGHT Nine lbs., including tape. PHYSICAL SIZE 14" long, 7½" wide, 4" deep. POWER REQUIREMENTS 28v DC, 150 MA. STEPPING RATE Two steps per minute max. READING Bi-directional. SWITCHING Form C switching providing an assert or negate status of each code bit being read. Switching activated by "star wheel" tape sensors.

TALLY
SEATTLE

TALLY REGISTER CORPORATION
1310 Mercer Street • Seattle 9, Washington • MAin 4-0760

Come to Seattle's Century 21 Exposition, April 21-October 21, 1962

CIRCLE 43 ON READER SERVICE CARD

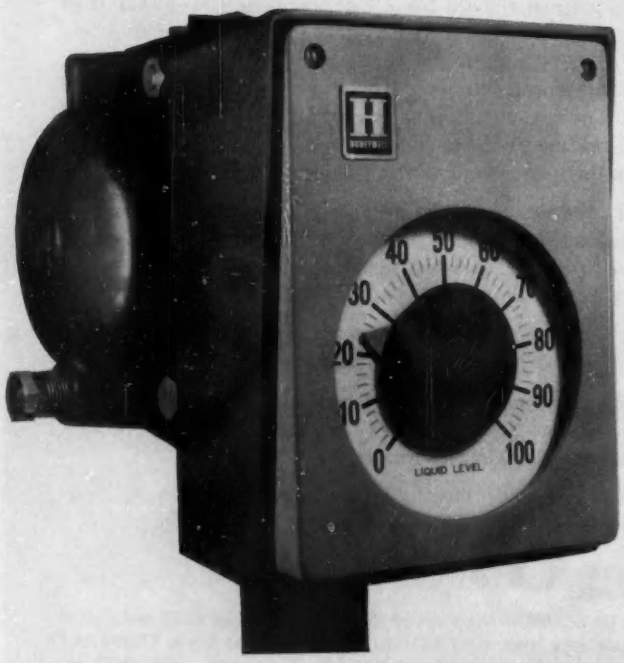
NEW BELLOWS FLOW TRANSMITTER

gives you field indication plus convenience and precision



You get all the economy and convenience of pneumatic transmission and all the efficiency of the bellows meter body plus field indication, when needed, in the new Honeywell Bellows Flow Transmitter. Use it in any application to transmit flow or liquid level measurements in open or closed tanks.

This new meter has automatic ambient temperature compensation and two-way overload protection for 100% of rated meter body pressure. Maintenance is greatly simplified by modular construction which lets you remove any major component by loosening two screws. All field adjustments are easily accessible, and a self-locking feature prevents upset after calibration adjustments are made.



New Bellows Transmitter is available with a concentric scale or as a non-indicator. It has 16 ranges—from 0-10 inches of water to 0-400 inches of water.

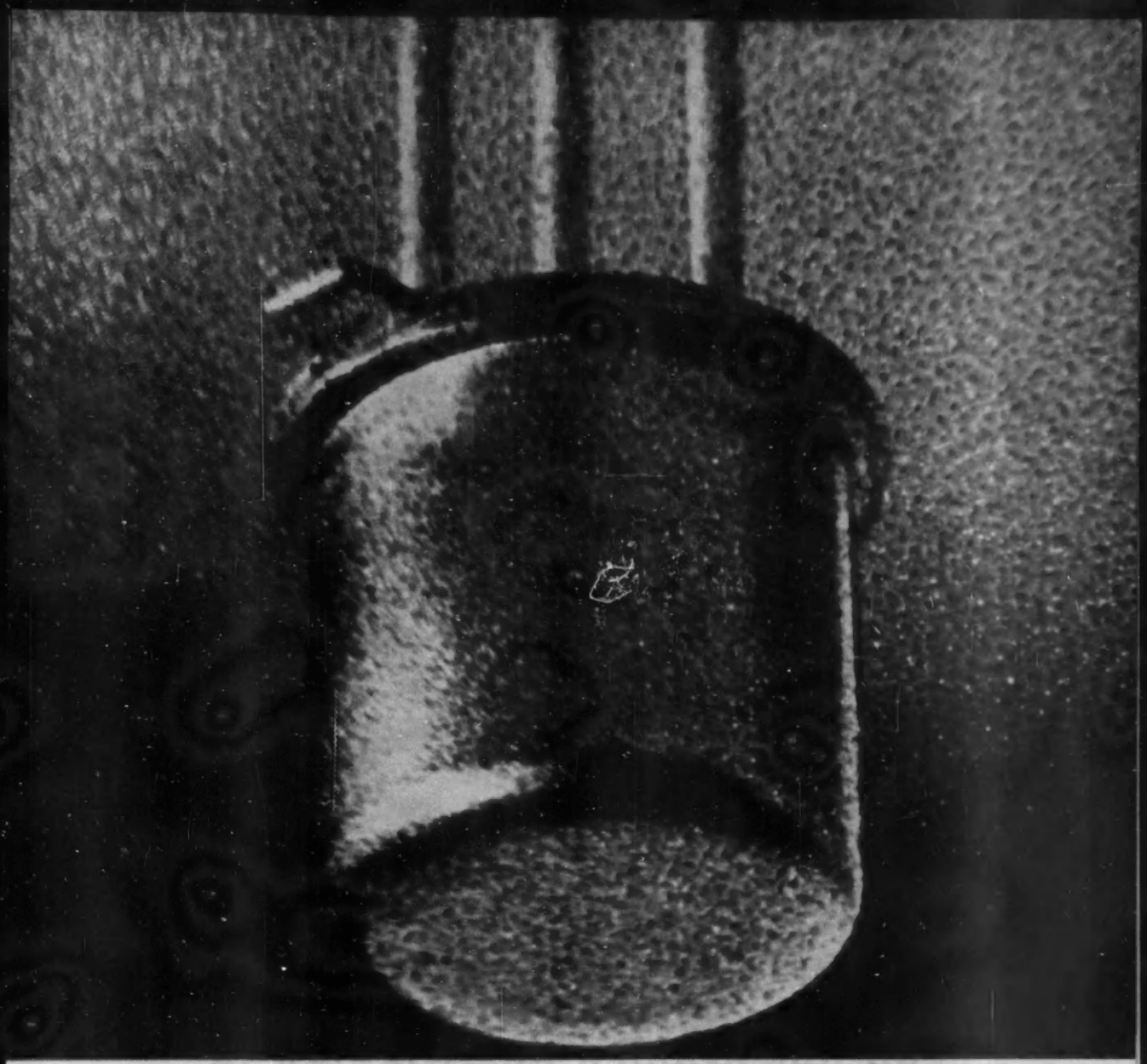
You can change ranges in the field simply by removing a single spring assembly and replacing it with an assembly of the desired range . . . adjust damping quickly and accurately, while the instrument is in operation . . . install the meter with either vertical or horizontal piping, so that it vents, drains and purges itself. The meter transmits with calibrated accuracy of ±0.5% of full scale, and indicates within ±1.0% of full scale.

For complete details on the new Bellows Flow Transmitter, call your nearby Honeywell field engineer. Or write MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.—In Canada, Honeywell Controls, Ltd., Toronto 17, Ontario.

Honeywell

First in Control

SINCE 1885



GENERAL INSTRUMENT SILICON PLANAR EPITAXIAL TRANSISTORS

SOURCE FOR SILICON PLANAR EPITAXIAL TRANSISTORS: 2N1613 2N696* 2N697* 2N698 2N699 2N1711 2N1252 2N1253 2N1410 2N1893 2N1958 2N1959 2N1990 □ 2N914 2N706* 2N706A 2N706B 2N707 2N708 2N743 2N744 2N753 2N783 2N784 2N834



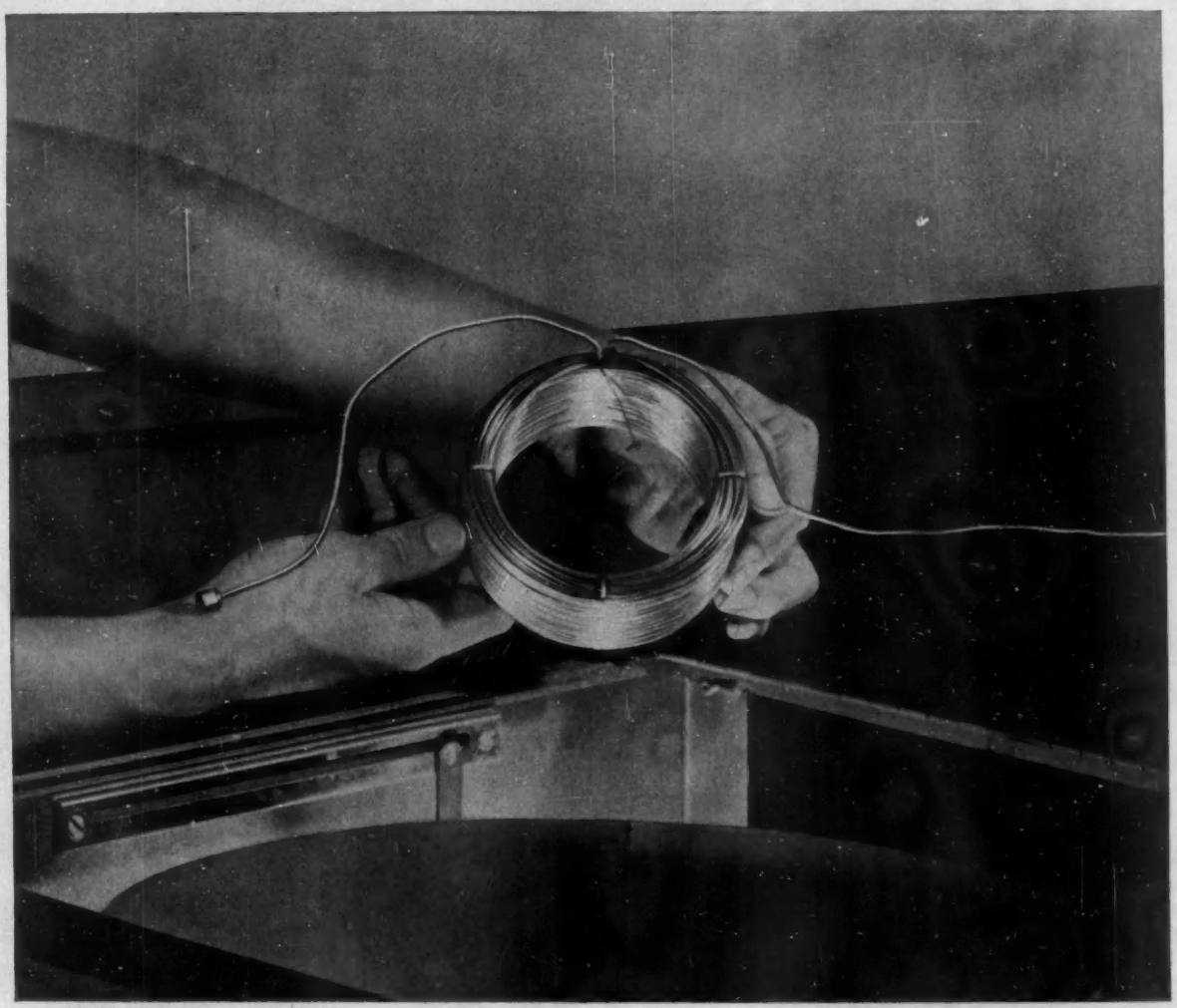
* available to Mil specification

GENERAL INSTRUMENT SEMICONDUCTOR DIVISION

GENERAL INSTRUMENT CORPORATION · NEWARK 4, NEW JERSEY

CIRCLE 45 ON READER SERVICE CARD

Tomorrow's tubing technology—today



Photograph courtesy Barber-Coleman Company

You get precise partitioning in gas chromatography tubing by Superior

The reason is a composite of many outstanding advantages: desirable inner surface, uniform bore and size, good corrosion resistance, high temperature resistance, ease in fabricating and bending; also good heat transfer characteristics and the ability to receive a wide variety of coatings.

Superior offers tubing for gas chromatography columns in Types 304, 316, 321 and 347 stainless steels and in 30% cupronickel. Capillary tubing sizes include 1/16 in. OD x .010 in., .016 in. and .020 in. ID. ODs to 1/8 in. and intermediate and larger IDs are available. We also make tubing for miniature columns, the most common size being .020 in. OD x .010 in. ID. Tubing for packed columns is available in 1/4 in. OD x 3/16 in. ID. And remember if you need small-diameter tubing for other purposes, we can help you too. We produce more than 120 analyses in sizes from .010 to 5/8 in. OD in quantities from 50 to over 1,000,000 ft. Superior Tube Company, 2026 Germantown Ave., Norristown, Pa. Write for Bulletin 110—"Tubing for Gas Chromatography."

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

West Coast: Pacific Tube Company, Los Angeles, California

Watch Weston for new concepts...



This miniature, electro hot-gas servo valve developed by Weston for the U.S. Army's "Mauler" Missile weighs only .18 pound.

Now Weston
GAS SERVOS
and **SYSTEMS**
offer new standards
of performance!

From this tiny gas actuated servo, to complete hot or cold gas-servo systems, Weston's pioneering of this advanced control concept has produced a practical design—proved reliable—and offering new standards of performance. ■ Eliminating the conventional "soft" response usually associated with gas actuators, this new design provides the fast forward response and positive reverse stiffness of a hydraulic system—yet operates way beyond the environmental limits of hydraulics. It can be stored indefinitely, has fewer components for greater inherent reliability, and up to 50% less weight than a hydraulic system. ■ A general bulletin is available on this new Weston design, and a specific proposal or a test demonstration can be arranged on request.



Development and test firing of Weston Gas Servo Systems are conducted in this special laboratory.

weston
HYDRAULICS LIMITED
A SUBSIDIARY OF BORG-WARNER CORPORATION

WESTON HYDRAULICS B-W BORG WARNER

7500 Tyrone Ave., Van Nuys, Calif. • Telephone TRiangle 3-4340

Mauler is being developed by Convair/Pomona, Convair Division of General Dynamics, for the Army Rocket and Guided Missile Agency, an element of the Army Ordnance Missile Command.

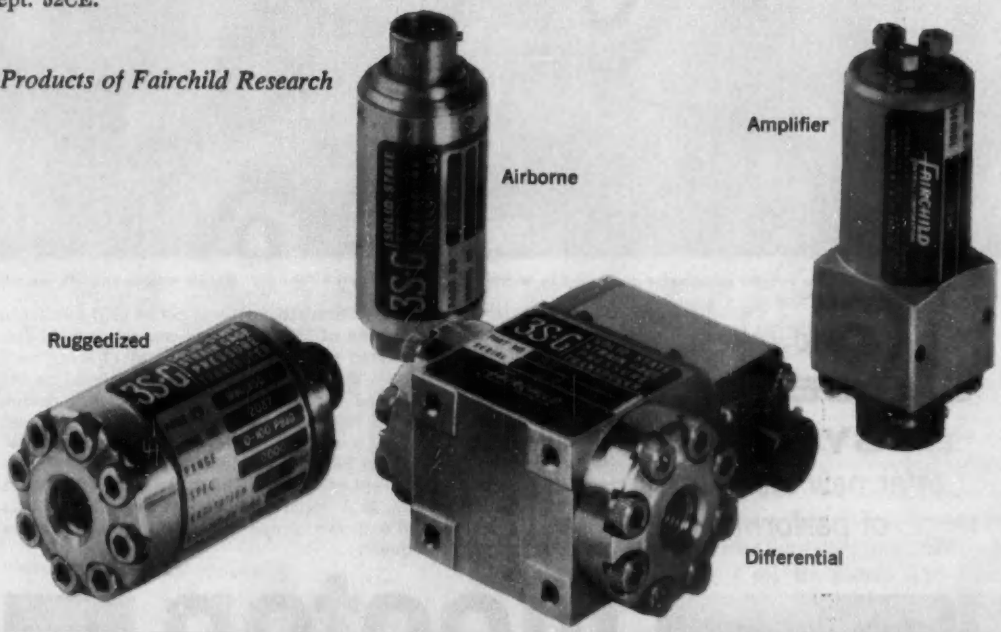
FROM FAIRCHILD RESEARCH IN SOLID-STATE

A COMPLETE NEW FAMILY...

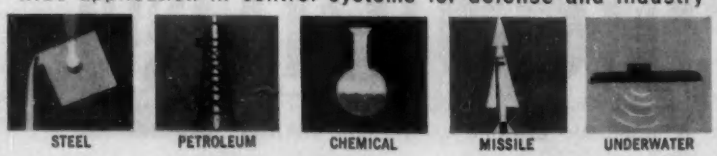
OF 3S-G SILICON-SEMICONDUCTOR STRAIN-GAGE PRESSURE TRANSDUCERS

Out of continuing research in solid state has come the 3S-G family of silicon-semiconductor strain-gage pressure transducers *with accuracy as high as ±.003% FS/Deg. F* and the new Fairchild d.c. differential amplifier for transducer applications. Tough, tiny, and extraordinarily accurate, the transducers offer the best characteristics of strain-gage and potentiometer-type transducers plus the advantages of piezoresistive silicon-semiconductor sensing elements. ■ Fairchild 3S-G transducers have infinite resolution, self-contained calibration, unexcelled repeatability, and extremely high output signal. Internal temperature compensation from zero to 150° F is standard. Compensation over entire operating temperature range from −65° F to 250° F is available on special order. Designed for new systems and interchangeable with existing military and industrial instruments, they will operate in practically all gaseous and liquid media. Pressure ranges are from 0-10 through 0-10,000 p.s.i.g. or p.s.i.a. Accuracy is as high as ±.003% FS/degree F (error band). Combined linearity and hysteresis is as good as .05% terminal. Standard output is either 50 mv. or ¼ v. or 5 v.d.c. (5 mv. to 5 v. available). The higher output range is especially valuable for transmission over a long line without additional amplification. ■ The Fairchild family of 3S-G pressure transducers includes low-pressure gage and absolute, high-pressure gage and absolute, and high-line low-differential instruments. In addition, there is a zero-drift solid-state d.c. amplifier. Absolute and gage transducers are available in ruggedized and airborne versions. Suppressed or offset ranges are available in all transducers. All have significant applications for precise measurement, testing and control of pressure in underwater, ground support, and airborne systems. All are available from stock for immediate delivery. ■ For more information about Fairchild 3S-G pressure transducers, write Dept. 52CE.

Finest Products of Fairchild Research



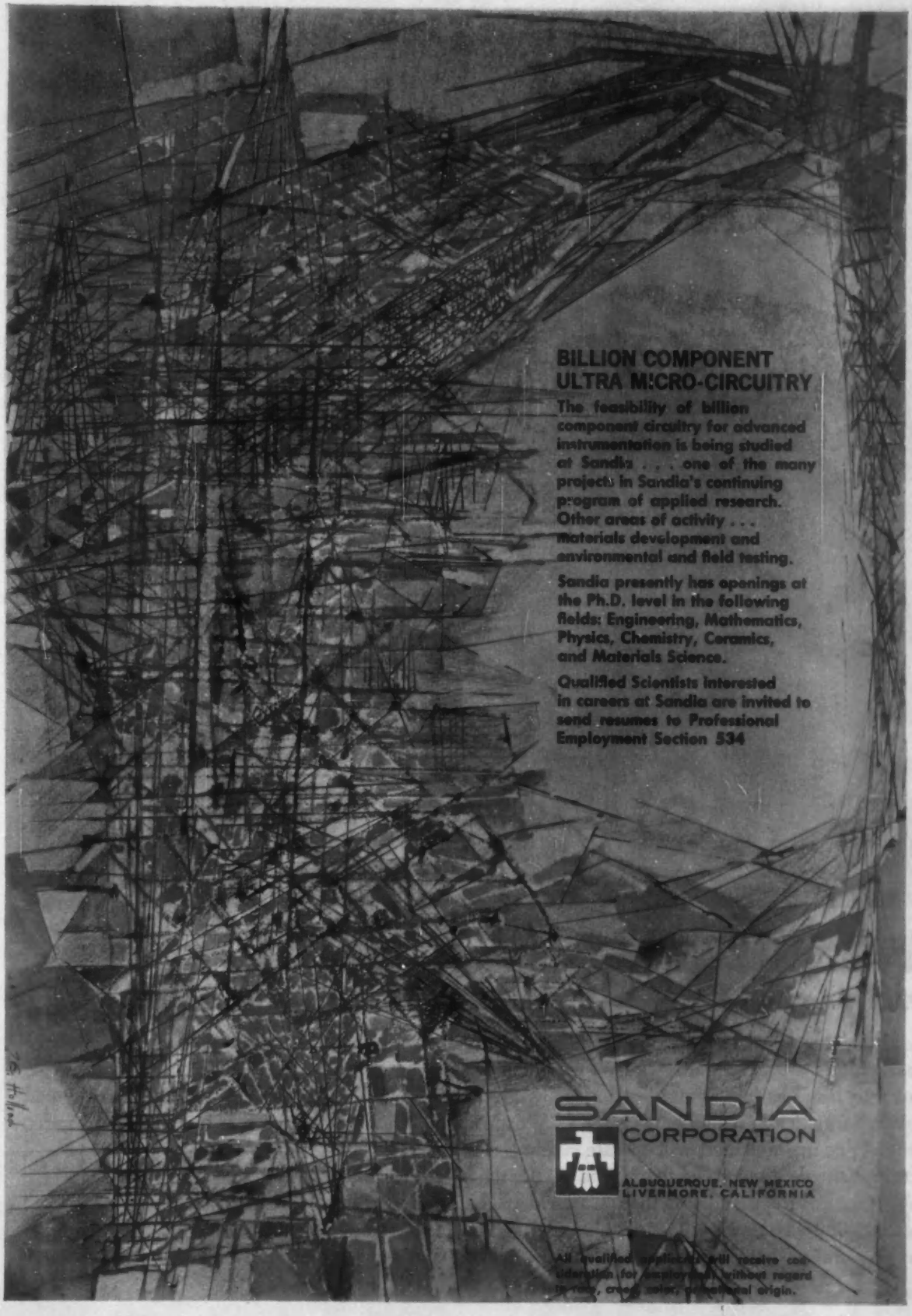
wide application in control systems for defense and industry

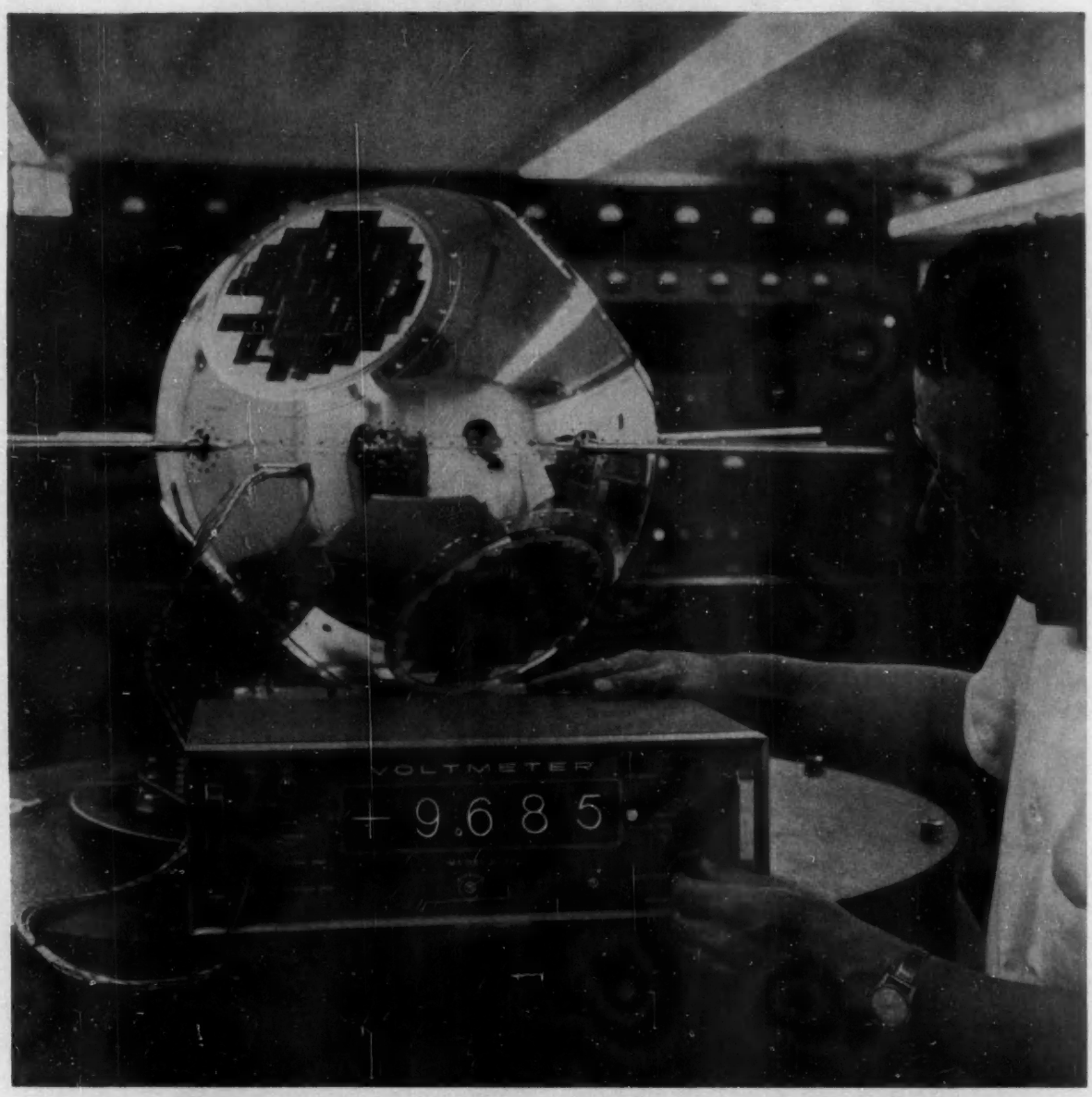


FAIRCHILD CONTROLS CORPORATION
A Subsidiary of Fairchild Camera and Instrument Corporation

GYROS
PRESSURE TRANSDUCERS
POTENTIOMETERS
ACCELEROMETERS

225 Park Ave., Hicksville, L. I., N. Y.
6111 E. Washington Blvd., Los Angeles, Cal.


BILLION COMPONENT
ULTRA MICRO-CIRCUITRY
The feasibility of billion component circuitry for advanced instrumentation is being studied at Sandia . . . one of the many projects in Sandia's continuing program of applied research. Other areas of activity . . . materials development and environmental and field testing.
Sandia presently has openings at the Ph.D. level in the following fields: Engineering, Mathematics, Physics, Chemistry, Ceramics, and Materials Science.
Qualified Scientists interested in careers at Sandia are invited to send resumes to Professional Employment Section 534
SANDIA
CORPORATION
ALBUQUERQUE, NEW MEXICO
LIVERMORE, CALIFORNIA
All qualified applicants will receive consideration for employment without regard to race, creed, color, or national origin.



NEW DVM CONCEPT!

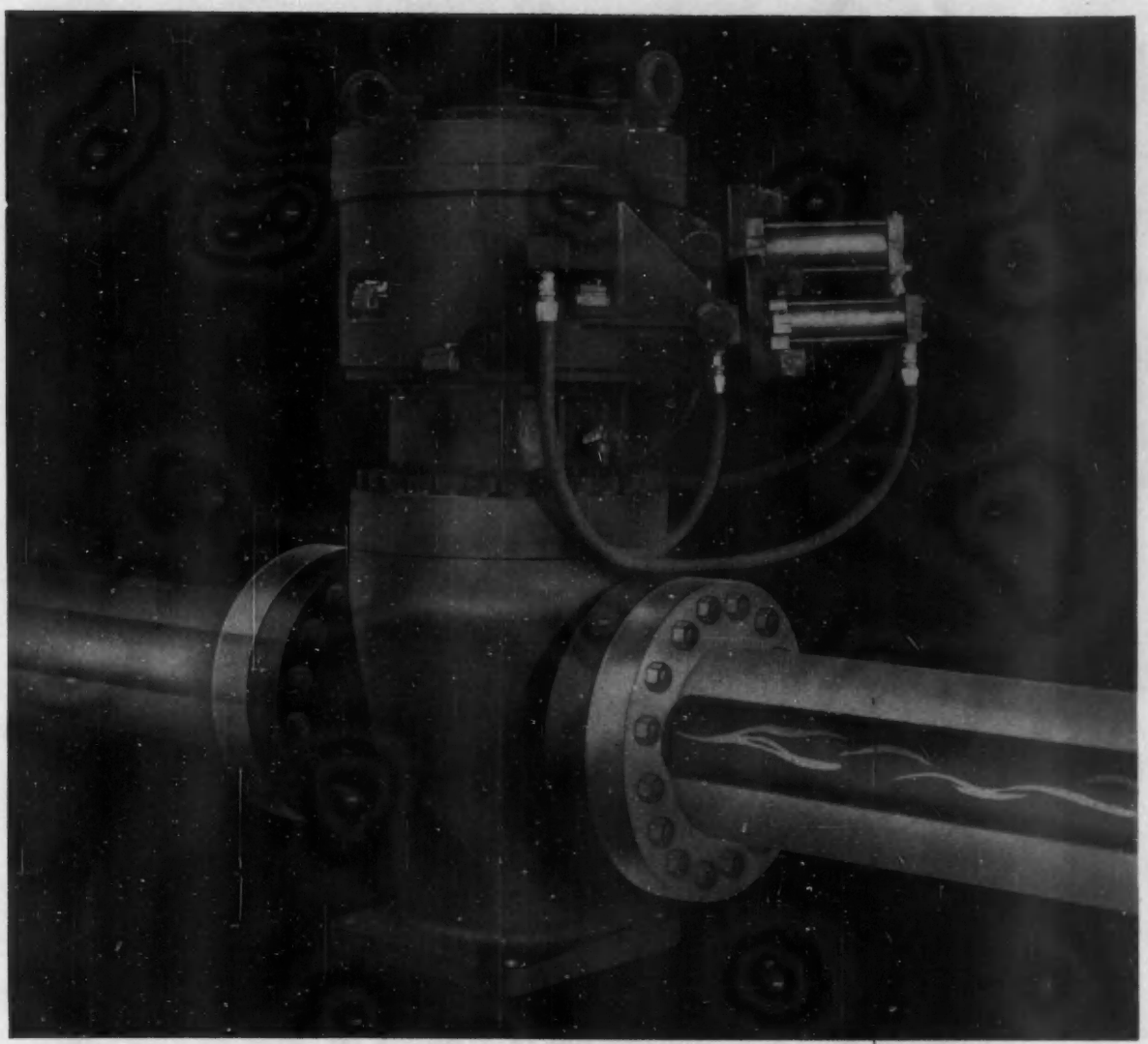
FAST: *Two readings per second* ***ACCURATE:*** *0.01% accuracy* ***LOW COST:*** *Only $1,580*

In the above test of a satellite's telemetry and solar cells, it was necessary to make 100 accurate measurements every minute. The job was done with the new Cubic V-70 digital voltmeter that reads out four times as fast as any instrument with stepping switches. The V-70 uses ultra-reliable reed relays hermetically sealed in glass for a life expectancy of at least 10 years. It has no moving parts, requires no maintenance, will operate in any position, and is resistant to thermal and physical shock. The V-70 is the only DVM offering 0.01% accuracy and less than 1 second balance time for less than $2,000 (Model V-70, $1,580; Model V-71 with automatic ranging and polarity, $2,200). For details, write to Dept. CT-108.

cubic CORPORATION
INDUSTRIAL DIVISION
SAN DIEGO 11, CALIFORNIA

OTHER OFFICES: LOS ANGELES, CALIFORNIA • ROME, ITALY (CUBIC EUROPA S.p.A.) • REPRESENTATIVES IN PRINCIPAL U.S. AND CANADIAN CITIES

ALLIS-CHALMERS



Rotovalve is an Allis-Chalmers trademark.

Featured 8-in. Rotovalve stands 7 ft high and weighs 50,000 lb. Hydraulic operator works at a pressure of 3000 psi . . . a speed of 1/10th second!

"Putting a stop" to 2500 psi at 2500 F

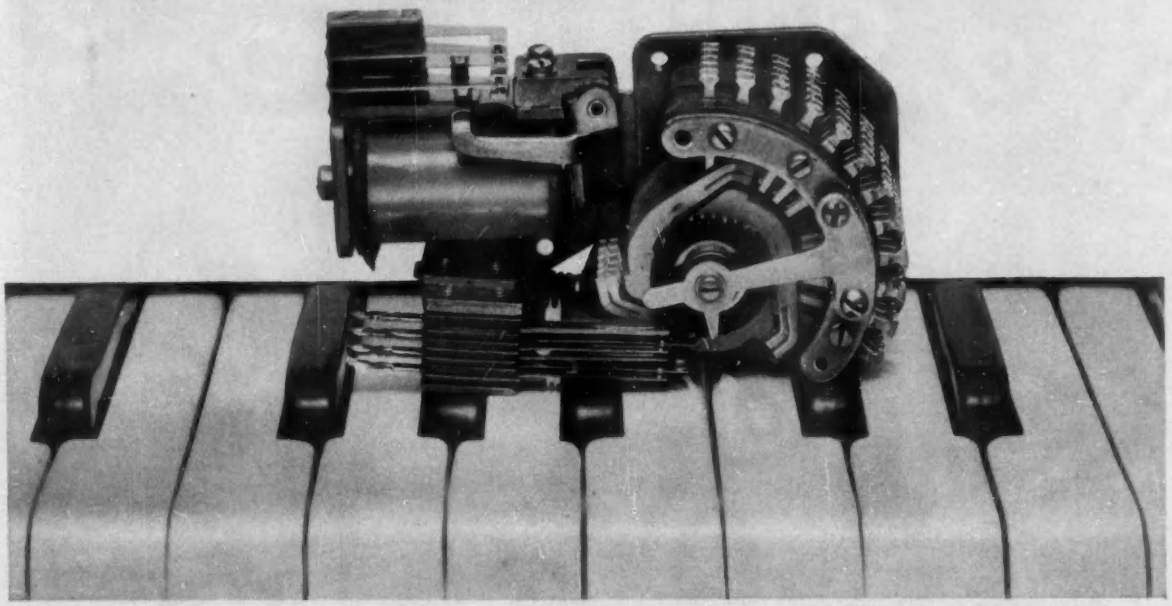
...here's the valve that does it with ease!

This 8-in. *Rotovalve* takes extreme conditions in stride . . . handles 2500 psi at 2500 F. Constructed of chrome-moly steel, it employs internal air cooling to maintain valve temperature at 1000 F despite the *far higher* heat of the liquid or gas being handled.

Allis-Chalmers cone valves *seat even tighter with use* . . . feature lantern ring with double packing, pressurized with the line fluid or purged to a bleed tank at lantern ring. Both standard and special *Rotovalve* units have proved their reliability in thousands of applications, under widely varying conditions.

Any time you face a valving problem, call on your Allis-Chalmers representative. He's equipped to supply "specials" engineered exactly to your application. And he also offers you a complete line of Rotovalve *units and butterfly valves for conventional uses. Contact him for information, or write* **Allis-Chalmers,** *Hydraulic Division, York, Pa.* A-1394

AE



To the Engineer

looking for a small-scale switch to do a large-scale job

If you have to perform complex switching maneuvers, fast, and in small space, you'll go for AE's Type 44 Rotary Stepping Switch.

This mere handful of rugged switching accommodates up to six bank levels, with 10 points plus home—will do the work normally assigned to whole banks of relays.

The miniature Type 44, and its big brother, Type 45, are the only stepping switches with a positive-action, free-floating pawl. This unique design eliminates armature-stop and pawl-stop readjustment – prevents pawl wear-and-tear, breakage, and binding. The pawl locking teeth position the rotor automatically, making overthrow impossible.

For data processing or high-speed control, AE's new Type 40 is a truly "decimal" rotary stepping switch, with only ten positions instead of eleven. Featuring especially high dielectric molded banks, it is also available with Taper Tab terminals and hermetically sealed, if required. For full data write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois. Ask for Circular 1698-J.

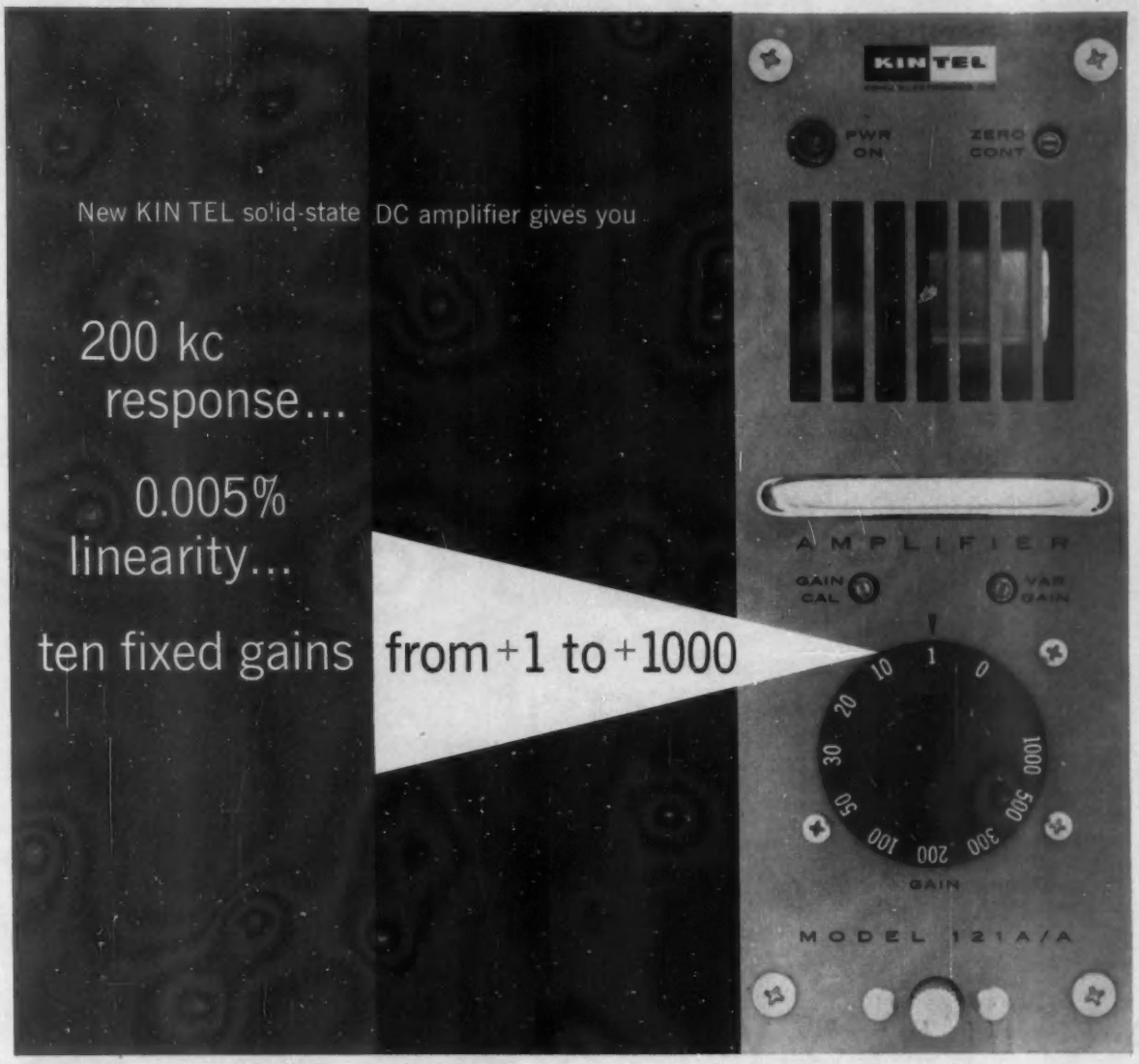


AUTOMATIC ELECTRIC

Subsidiary of

GENERAL TELEPHONE & ELECTRONICS

GENERAL SYSTEM



KIN TEL's Model 121A/A non-inverting DC amplifier has fixed gains of 0, +1, +10, +20, +30, +50, +100, +200, +300, +500, and +1000. A variable gain control adjusts any fixed gain from x1 to x2.2. A gain calibration control gives ±2.5% adjustment for each gain other than +1.

With this new instrument, you can amplify accurately all low-level signals from DC to beyond 200 kc for the reliable measurement of strain, temperature, flow, vibration, displacement, or other physical phenomena. The 121A/A has the same dimensions, fits the same cabinets and modules as other KIN TEL DC amplifiers.

For more information on this new, more *usable* DC amplifier, write to KIN TEL. Engineering representatives in all major cities.

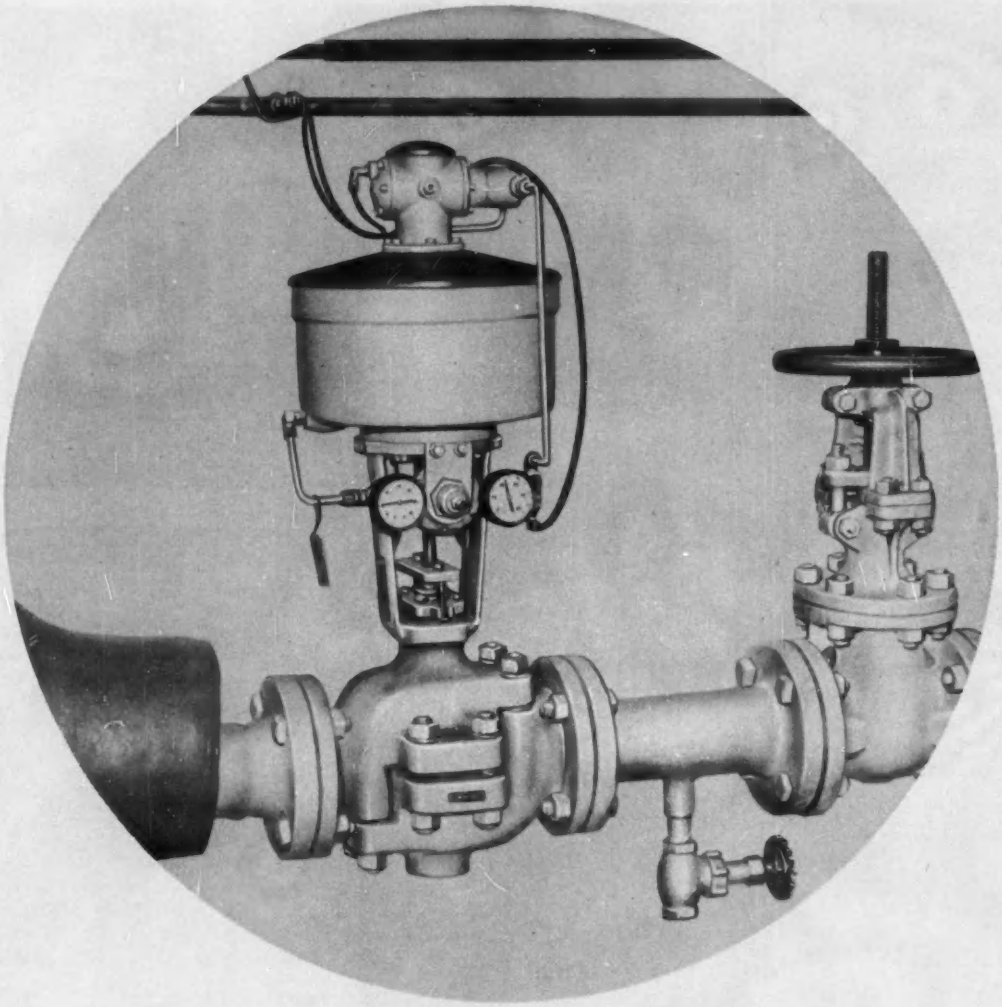
ADDITIONAL SPECIFICATION NOTES:

The Model 121A/A is a non-inverting (positive input produces a positive output), wideband, DC amplifier. Amplification is accurate within 0.1% for all gains other than +1 (gain accuracy is 0.2% at +1), linear within 0.005% for outputs up to ±15 volts DC with load impedances of 200 ohms or more. The amplifier provides up to 100 ma – ±DC or peak AC – into loads of 100 ohms or less. Input impedance is greater than 10 megohms; output impedance is less than 0.3 ohm. Frequency response is flat within 0.25% to 2 kc, within 4% to 10 kc, within 3 db to 200 kc. Drift is less than ±2.0 μvolts equivalent input for over 40 hours at +1000 gain. Amplifier recovers from 100% overload in 0.4 second, is undamaged by sustained, direct short across output terminals. Price $1000.

5725 Kearny Villa Road, San Diego 11, California • BRowning 7-6700

KIN TEL
A DIVISION OF
COHU
ELECTRONICS, INC.

CIRCLE 53 ON READER SERVICE CARD 53



A Split-body Valve is not a "Specialty"

...it is a practical, all-purpose control valve

The Conoflow Series LB valve shown is handling 100 psi steam. This is not unusual. Actually, the vast majority of the thousands of LB valves in service are handling water, steam and other common plant fluids. In fact, more than 80% of LB orders call for *standard* cast steel or ductile iron construction.

LB valves were selected because they give *better control, greater dependability* and *unequalled maintenance savings,* all at a *low initial cost.*

More and more users are standardizing on the LB valve right down the line because they know that LB valves mean *less downtime,* resulting in a more profitable plant operation.



Write for NEW Bulletin LB-4. Be convinced.

CONOFLOW SUBSIDIARY WAUKESHA

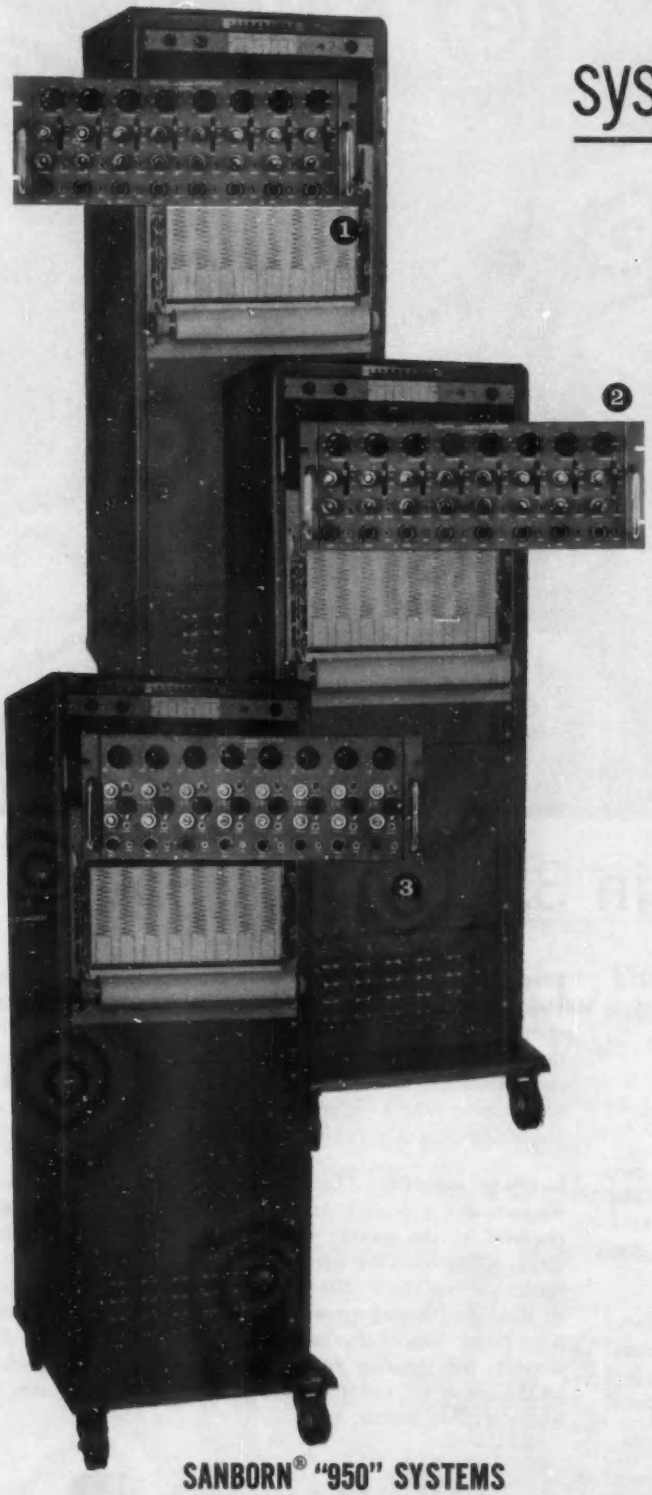
CONOFLOW CORPORATION

FOREMOST IN FINAL CONTROL ELEMENTS

2100 ARCH STREET, PHILADELPHIA 3, PA.

CC110

match system sensitivity to your recording application



SANBORN® "950" SYSTEMS

Dynamic demonstrations of 950 Systems and other Sanborn oscillographic recording equipment at WESCON, Aug. 22-25 Booths 2014-2016

When your recording application calls for 6 or 8 direct writing, general purpose channels with identical sensitivity and input electronics, Sanborn "950" design provides a highly useful, economical answer in the precise sensitivity range you need. Choices include systems with:

1 HIGH GAIN AMPLIFICATION . . . 6 or 8 transistorized channels with floating and guarded inputs, 100,000 ohms resistance on all ranges, 10 to 2000 uv/div sensitivity. System response DC to 100 cps within 3 db at 10 div peak-to-peak amplitude. Common mode performance ±200 volts, max., rejection 140 db min. at DC. High gain stability, max. non-linearity 0.5%, low noise and drift. All channels have range, gain, function, position and galvanometer frequency compensation controls.

2 MEDIUM GAIN AMPLIFICATION . . . 6 or 8 transistorized channels with floating and guarded inputs; ½ meg. resistance on mv ranges, 1 meg. on volt ranges; sensitivity 0.5 to 20 mv/div and volts/10 div. System response DC to 150 cps within 3 db at 10 div peak-to-peak amplitude. Common mode voltage ±500 volts, max., rejection 140 db min. at DC. Same controls as High Gain amplifier.

3 LOW GAIN AMPLIFICATION . . . 6 or 8 channels, balanced to ground inputs 5 meg. each side; tube and transistor circuitry; sensitivity 10 to 500 mv/div and 1 to 10 volts/div. System response same as Medium Gain system. Common mode performance ±2.5 volts and 34 db min. rejection on most sensitive range. Amplifier available with or without Calibrated Zero Suppression.

All "950" systems have 350-style 6- or 8-channel flush-front, heated stylus recorder, using Sanborn rectangular-coordinate Permapaper.® Nine chart speeds, timer/marker stylus, built-in paper take-up. Systems housed in 63⅛" high mobile cabinets; amplifier and recorder occupy only 24½" of panel space. For complete descriptive literature and application assistance, call your Sanborn Industrial Sales-Engineering Representative; offices throughout the U. S., Canada and foreign countries.

INDUSTRIAL DIVISION
SANBORN COMPANY
175 Wyman St., Waltham 54, Mass.

CIRCLE 55 ON READER SERVICE CARD 55



Seven 2" Scopes in 3½" of Rack Space!

New EI solid state scopes combine small size with exceptionally high performance to provide the ideal instrumentation scopes for displaying multi-channel electrical phenomena.

High performance—Each Model 260M incorporates its own independent sweep and vertical circuits. The vertical amplifier provides a bandwidth of from DC to 1 megacycle with horizontal sweep rates of from 10 cps to 100 kc. Use of a 2", flat-faced CRT provides a bright, precision display.

Compact size—Each individual scope requires no more front panel area than a needle movement meter and only 16" behind the panel. The compactness saves at least 45 inches of panel space when compared with the same number of conventional instruments.

Solid state reliability—Totally transistorized circuits eliminate the ever present problem of heat flow to adjacent equipment, and the operational aging so often associated with vacuum tube amplifiers.

Simple, rugged construction—All components are mounted on plug-in printed circuit boards. The controls required most frequently—sweep range and sweep vernier—are positioned on the front panel for operational adjustment, while all others are easily accessible at the top rear of the scope chassis. Individual scopes plug into a separate power supply rack capable of accommodating seven units.

Maximum versatility—The plug-in nature of each individual scope makes it possible to obtain only the number of units required for the specific task, with adequate provisions for future additions as the need arises. For applications involving the use of the Model 260 with multi-channel tape recorders, an additional record-reproduce switch is incorporated on the front panel. Use of this switch allows the connection of the scope to two separate inputs. Versatility is further extended by the use of DC coupling, a feature normally found only in laboratory instruments.

Ask your EI field engineer for complete specifications

E I

Engineers: Challenging opportunities now available. Contact Mr. Harvey Fleming.

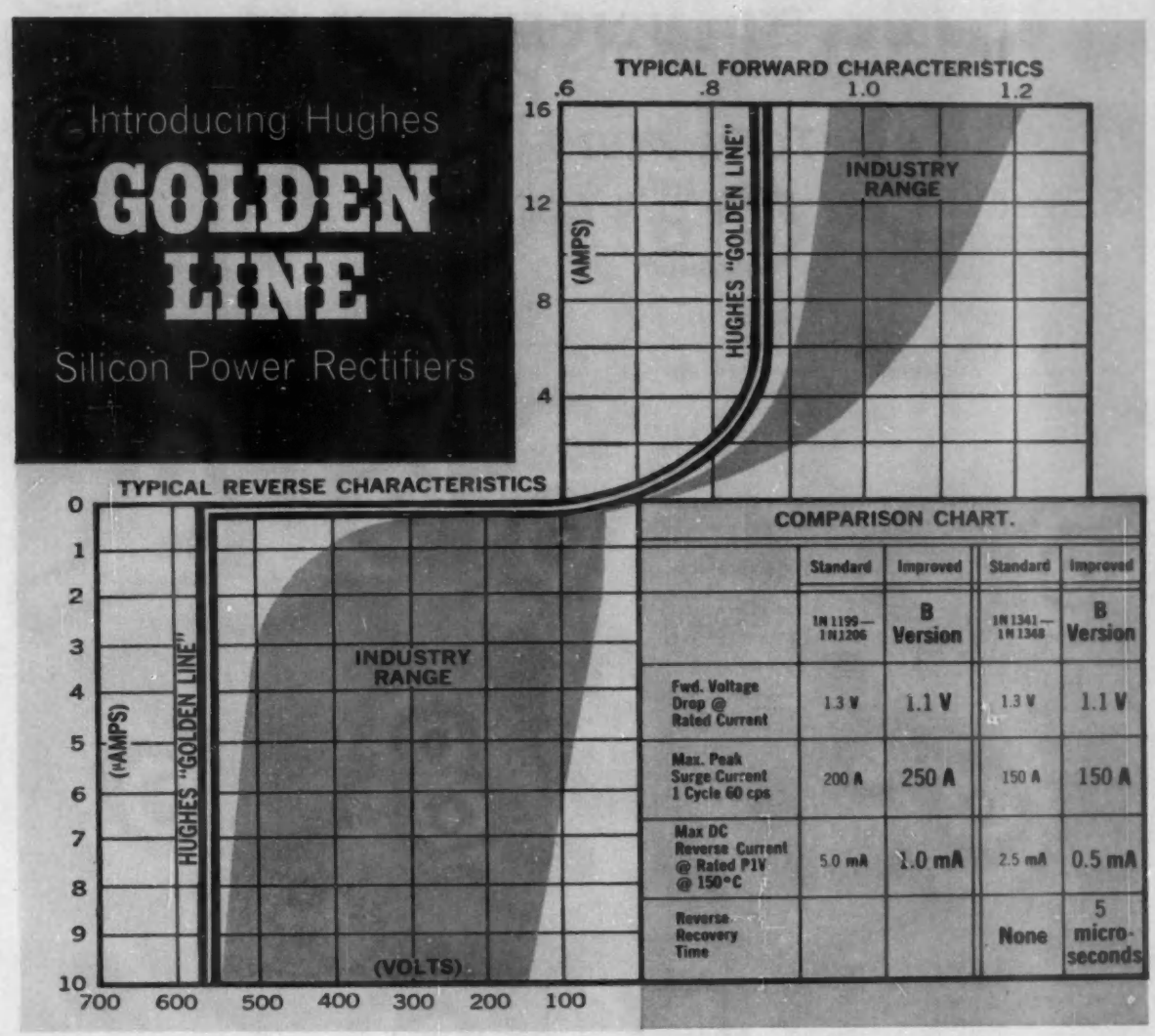
Electro Instruments, Inc. / 8611 BALBOA AVENUE, SAN DIEGO 11, CALIFORNIA

CIRCLE 56 ON READER SERVICE CARD

Introducing Hughes

GOLDEN LINE

Silicon Power Rectifiers



COMPARISON CHART.

	Standard	Improved	Standard	Improved
	1N 1199—1N 1206	B Version	1N 1341—1N 1348	B Version
Fwd. Voltage Drop @ Rated Current	1.3 V	1.1 V	1.3 V	1.1 V
Max. Peak Surge Current 1 Cycle 60 cps	200 A	250 A	150 A	150 A
Max DC Reverse Current @ Rated PIV @ 150°C	5.0 mA	1.0 mA	2.5 mA	0.5 mA
Reverse Recovery Time			None	5 micro-seconds

Here are eight big reasons why you should buy Hughes silicon power rectifiers. Let us prove their superiority right in your plant.

1. Low Reverse Leakage—Typically less than one microamp. at rated voltage at room temperature. **2. High Reverse Stability**—All units 100% heat-soaked at 200°c for 200 hours. **3. Low Forward Voltage Drop**—Typical units will have a forward voltage drop of less than one volt at rated current. **4. Fast Reverse Recovery**—Typically less than 2.0 microseconds! **5. Low Dynamic Impedance**—Typically .0035 ohms at rated current. **6. Low Thermal Impedance**—Typically 2°c per watt. **7. High Current Surge Capability**—Up to 240 amps. for one cycle 60 cps non-recurrent. **8. No Junction Stress**—The Golden Line has a fine silver braided internal lead wire that adjusts for thermal expansion and contraction. Hughes silicon rectifiers are available with regular stud or with insulated type stud for even greater heat dissipation.

Hughes Golden Line Rectifiers available immediately. *Call your Hughes representative or authorized Hughes distributor.*



HOW TO SEE THE GOLDEN LINE IN ACTION

We are so certain of the performance of the Golden Line of power rectifiers we have supplied all our salesmen with special comparison kits. They will bring these kits right into your plant and show you how they compare with the *best* rectifiers you are now using. For complete Golden Line data sheets, write Hughes Semiconductor Division, Marketing Department, Newport Beach, California.

CREATING A NEW WORLD WITH ELECTRONICS

HUGHES

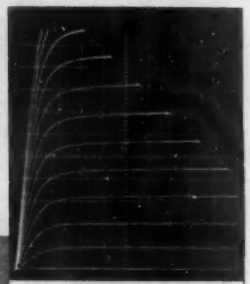
HUGHES AIRCRAFT COMPANY

SEMICONDUCTOR DIVISION

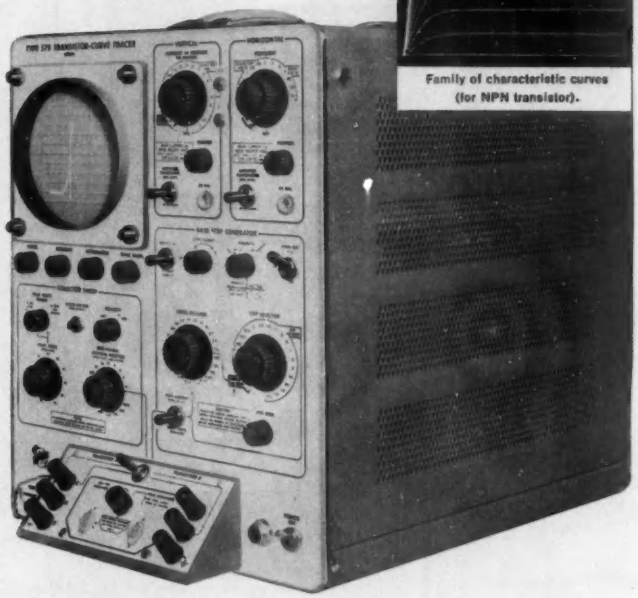
CIRCLE 57 ON READER SERVICE CARD 57

TEKTRONIX TRANSISTOR-CURVE TRACER

INVALUABLE TOOL FOR EVALUATING SEMICONDUCTOR DEVICES



Family of characteristic curves (for NPN transistor).



The Type 575 provides 20-ampere collector displays (10-ampere average supply current), two ranges of collector supply (0 to 20 volts, 0 to 200 volts), and 2.4-ampere base supply (positive or negative base stepping).

With a Type 575, you can plot and measure 7 different transistor characteristics. You can display 4 to 12 curves per family—with input current from 1 microampere/step to 200 milliamperes/step or input voltage from 10 millivolts/step to 200 millivolts/step—in repetitive or single-family presentations. You can select either common-emitter or common-base configurations.

Add a Type 175 Adapter and you extend the range of collector displays 10 times and the range of base supply 5 times.

You can also test diodes under a wide variety of conditions and observe waveform characteristics on the 5-inch crt with a high degree of accuracy.

Type 575 Calibrated Displays

Vertical Axis—Collector Current, 16 steps from 0.01 ma/div to 1000 ma/div. Pushbuttons are provided for multiplying each current step by 2 and dividing by 10, increasing the current range to 0.001 ma/div to 2000 ma/div.

Horizontal Axis—Collector Voltage, 11 steps from 0.01 v/div to 20 v/div.

Both Axes—Base Voltage, 6 steps from 0.01 v/div to 0.5 v/div. Base Current, 17 steps from 0.001 ma/div to 200 ma/div. Base Source Voltage, 5 steps from 0.01 v/div to 0.2 v/div.

Type 575 Transistor-Curve Tracer $975

HIGH-CURRENT ADAPTER

For measuring high-powered semiconductor devices which exceed the current capabilities of a Type 575, ask your Tektronix Field Engineer about the Type 175 High-Current Adapter. Not intended for separate use, the Type 175 depends upon the circuitry and crt of a Type 575 to provide *200-ampere collector displays, three ranges of collector supply, and 12-ampere base supply*—for calibrated displays with Collector Current on the Vertical Axis and either Collector Voltage or Base Voltage on the Horizontal Axis.

Type 175 Transistor-Curve Tracer High-Current Adapter $1425



HIGH-VOLTAGE TYPE 575

Supplied on order from your Tektronix Field Engineer is a special model of the Type 575 Transistor-Curve Tracer. Although similar to the Type 575, the special model provides much higher diode breakdown test voltage (*variable from zero to 1500 volts* at a maximum current of 1 milliampere) and also much higher Collector Supply (*up to 400 volts*, at 0.5 ampere).

For complete specifications of this special model—call your Tektronix Field Engineer.

Type 575 Mod 122C $1175

(prices f.o.b. factory)

. . . for more information about evaluating semiconductor devices with a Type 575 or other Tektronix test equipment, call your Tektronix Field Engineer. He will be glad to assist you.

Tektronix, Inc. *P. O. BOX 500 · BEAVERTON, OREGON / Mitchell 4-0161 · TWX—BEAV 311 · Cable: TEKTRONIX*

TEKTRONIX FIELD OFFICES: Albuquerque, N. Mex. • Atlanta, Ga. • Baltimore (Towson) Md. • Boston (Lexington) Mass. • Buffalo, N.Y. • Chicago (Park Ridge) Ill. • Cleveland, Ohio • Dallas, Texas • Dayton, Ohio Denver, Colo. • Detroit (Lathrup Village) Mich. • Endicott (Endwell) N.Y. • Greensboro, N.C. • Houston, Texas • Indianapolis, Ind. • Kansas City (Mission) Kan. • Los Angeles, Calif. Area (East Los Angeles, Encino • West Los Angeles) • Minneapolis, Minn. • Montreal, Quebec, Canada • New York City Area (Albertson, L.I., N.Y. • Stamford, Conn. • Union, N.J.) • Orlando, Fla. • Philadelphia, Pa. • Phoenix (Scottsdale) Ariz. Poughkeepsie, N.Y. • San Diego, Calif. • San Francisco, Calif. Area (Lafayette, Palo Alto) • St. Petersburg, Fla. • Syracuse, N.Y. • Toronto (Willowdale) Ont., Canada • Washington, D.C. (Annandale, Va.).

TEKTRONIX ENGINEERING REPRESENTATIVES: Hawthorne Electronics: Portland, Oregon; Seattle, Washington • Kentron Hawaii Ltd., Honolulu, Hawaii. Tektronix is represented in twenty overseas countries by qualified engineering organizations.

In Europe please contact Tektronix International A.G., Terrassenweg 1A, Zug, Switzerland, Phone (042) 4-91-92, for the address of the Tektronix Representative in your country.

Norden minimizes magnetic encoder size



BuOrd SIZE 18 GRAY-CODE MAGNETIC ENCODER SMALLEST AVAILABLE

NORDEN offers this new encoder for applications where the combination of exceptionally long wear and high speed operation in a smaller package are vital. Strengthen your system or product design with this new high standard of performance factors:

- **Smaller size.** 1.750″ diameter achieved by advanced techniques of ferrite disc magnetization.
- **High-speed performance.** Offers accurate readout at speeds to 10,000 rpm.
- **Almost unlimited life . . .** since encoder is not subject to disc-to-brush contact and wear.
- **Very low-starting and running torque.**
- **Completely unambiguous output.**

TYPICAL SPECIFICATIONS

Total Count	2^8 Gray Code
Rev./Full Count	1
Moment of Inertia	21 gm-cm²
Output Voltage	3 volts PTP min.
Breakaway Torque	Less than .05 oz/in
Maximum Speed (continuous interrogate)	10,000 rpm
Slew Speed	10,000 rpm
Diameter	1.750″
Weight	Under 5 oz.
Temperature Range	−65° to +125° C.
Vibration and Shock	Conforms to MilE-5272A

Send for more information on this unit and

OTHER MAGNETIC ENCODERS NOW AVAILABLE: Gray multi-turn size 18 with count capacities of 8, 15 and 22 digits; V-scan binary size 18 with capacities of 7, 13 and 19 digits; binary coded decimal with 8-4-2-1 or 4-2-2-1 code; pure binary or cyclic units with counts of 100, 1000, 10,000. Special disc patterns and count capacities can be produced to your requirements.

Advanced Norden techniques are also facilitating the development of SIZE 11 Gray and V-scan encoders offering this same capacity.

NORDEN division of **UNITED AIRCRAFT CORPORATION**

NORWALK, CONNECTICUT



PHOTOGRAPHS — COURTESY: REPUBLIC AVIATION

The Case For Pinpoint Recruiting

Pinpoint Recruiting (the act of going directly to the most concentrated source of supply to find 'the right man' for the job) can be termed the most efficient method of recruiting engineers, and yet it is the simplest of all methods.

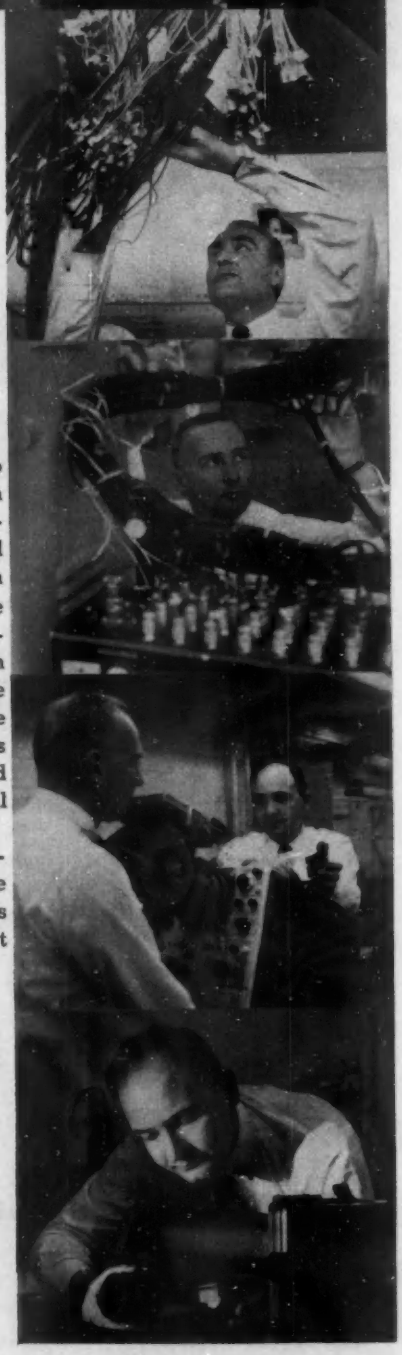
If you bear in mind the fact that the cream of the engineering talent you seek are presently employed and generally happy in their work, you realize that you must arouse their interest in YOUR company. As you know, engineers change jobs more frequently than does the average job holder . . . And so you ask yourself, "What motivates the engineer to do this?" To some, the answer may be surprising.

Studies in recent years have shown that the motivating factors are as follows:

1. Potential growth of company.
2. Challenging opportunity.
3. Starting salary.
4. Progressive research and development.
5. Company's prestige, reputation.
6. Regular salary increases.
7. Geographic location.
8. Permanent position.

Eight points to ponder, to weave into your recruitment advertising with skill, to attract the qualified engineers you need. When you have it all wrapped up, run your advertising in a technical publication that keeps the engineer abreast of technological developments in the industry to which he contributes his talents. It is simple reasoning that the publication the engineer pays his money to read is the one he reads most thoroughly and values most highly as his technical journal.

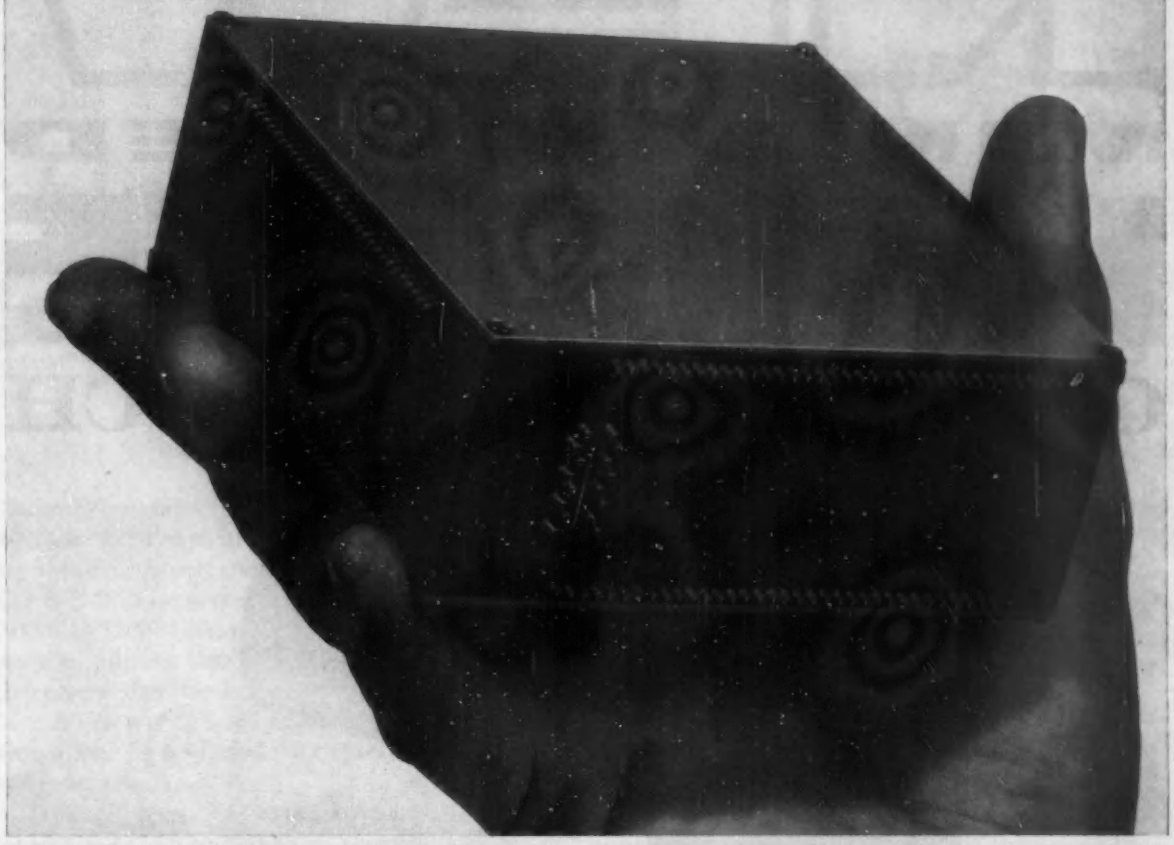
And there lies that "—most concentrated source of supply—" . . . of the experienced engineers you need. This is Pinpoint Recruiting. Simple, isn't it? . . . Effective, too.



Write for the new 52-page booklet ***"Recruiting Engineers"***
Address: David Hawksby, Classified Advertising Division, Control Engineering, Post Office Box 12, New York 36, N. Y.

Control ENGINEERING
INSTRUMENTATION AND CONTROL SYSTEMS
CLASSIFIED ADVERTISING DIVISION
POST OFFICE BOX 12 NEW YORK 36, NEW YORK

Now Pack More Data Into Every Cubic Inch with RCA HIGH DENSITY MEMORY STACKS...



TEMPERATURE CONTROLLED WITHIN ±2°C...DESIGNED TO MEET MIL SPECIFICATIONS

Occupying only 4.75 x 4.75 x 2 inches of space, this 4,096-word (8 bits per word) temperature-controlled magnetic-memory stack is available for a broad range of military, industrial and commercial computer applications.

RCA introduces new high density temperature-controlled memory stacks to meet the environmental extremes under which many of today's computers must operate. These new stacks incorporating RCA ferrite memory cores with specified wide operating margins are designed to cope with broad variations in power levels. In addition, they are built and tested to meet and exceed the environmental requirements of stringent military specifications.

MILITARY RELIABILITY: New RCA miniaturized high density memory stacks undergo and pass the MIL requirements pertaining to: Temperature Cycling, Vibration, Shock, Humidity, High Temperature, Barometric Pressure, Fungus Resistance, Salt Resistance. In addition, all stacks are 100 percent dynamically tested to assure the highest possible degree of dependability under actual computer operating conditions.

WIDE VARIETY: New RCA miniaturized memory stacks can be ordered in sizes to suit your requirements. Even the smallest temperature-controlled versions will maintain a temperature of + 85°C ± 2°C over free air temperatures ranging from − 55°C to ± 85°C. RCA temperature-controlled stacks reach their 85°C operating temperature in only 15 minutes.

With these new miniaturized memory stacks RCA now offers one of the industry's most comprehensive lines of memory components. RCA magnetic memory specialists are ready to custom design virtually any stack you specify.

SERVICE: Your local RCA Semiconductor and Materials Division Field Representative is prepared to provide a completely coordinated applications service covering transistors, tunnel diodes and other semiconductor diodes, ferrite components and memory systems. Call him today. For further technical information, write RCA Semiconductor and Materials Division, Commercial Engineering, Section I-56-NF, Somerville, N. J.

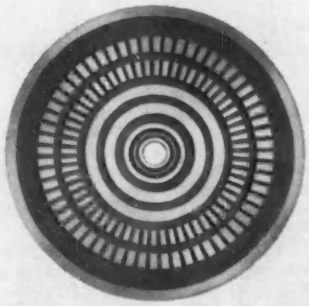
RCA® The Most Trusted Name in Electronics
RADIO CORPORATION OF AMERICA

RCA SEMICONDUCTOR & MATERIALS DIVISION... EAST: Newark, N. J., 744 Broad St., HUmboldt 5-3900 • (Camden, N. J. area), Erlton, N. J., 605 Marlton Pike, HAzel 8-4802 • Syracuse, N. Y., 731 James St., Room 402, GRanite 4-5591 • Baltimore, Md., ENterprise 9-1850 • **NORTHEAST:** Needham Heights 94, Mass., 64 "A" St., Hillcrest 4-7200 • **SOUTHEAST:** Orlando, Fla., 1520 Edgewater Drive, Suite #1, GArden 4-4768 • **EAST CENTRAL:** Detroit 2, Mich., 714 New Center Bldg., TRinity 5-5600 • **CENTRAL:** Chicago, Ill., Suite 1154, Merchandise Mart Plaza, WHitehall 4-2900 • Minneapolis, Minn., 5805 Excelsior Blvd., WEst 9-0676 • **WEST:** Los Angeles 54, Calif., Box 54074, RAymond 3-8361 • (San Francisco area), Burlingame, Calif., 1838 El Camino Real, OXford 7-1620 • **SOUTHWEST:** Dallas 7, Texas, 7905 Carpenter Freeway, FLeetwood 7-8167 • **GOV'T:** Dayton, Ohio, 224 N. Wilkinson St., BA 6-2366 • Washington, D.C., 1725 "K" St., N.W., FEderal 7-8500

NEW MINIATURIZED LONG-LIFE COMMUTATION SWITCH



ACTUAL SIZE
Plate dia. only 1 3/4"



. . . but 1¾" plate diameter and 50% space savings* in a 180-channel switch are only the start of the story. This new electromechanical switch also gives the other advantages that have made MYCALEX® units the industry standard. Noise level of less than 1 millivolt when switching 5 volts into a 150-ohm load. Up-to-a 1000 megohm resistance between rectangular contacts. Speeds as high as 1800 RPM. Metal-to-metal wiping action that prevents graphite build-up. Super-hard, gold-plated contacts. SUPRAMICA® 555 ceramoplastic plate that withstands operating temperatures to 650° F., has *total* dimensional stability, locks contacts in place. *Plus* nylon-brush mountings of new design that eliminate bounce and deliver sharp, clean signal edges.

Whether you're looking for commutation plates or complete switches, it'll pay you to investigate both of these compact, new components which give you an additional degree of design latitude. (For example, other MYCALEX switches offer up to 540 contacts on a 3"-diameter plate.) Write today for our new, comprehensive technical bulletin.

**When compared with conventional Inter-Range Instrumentation Group Telemetering Switches.*

General Offices and Plant: 127 Clifton Boulevard, Clifton, N. J.
Executive Offices: 30 Rockefeller Plaza, New York 20, N. Y.

SYNTHAMICA® SYNTHETIC MICA · SINCE 1919 MYCALEX® THE INSULATOR · SUPRAMICA® CERAMOPLASTIC

MYCALEX
ELECTRONICS CORPORATION

EXCLUSIVE LICENSEE OF MYCALEX CORPORATION OF AMERICA

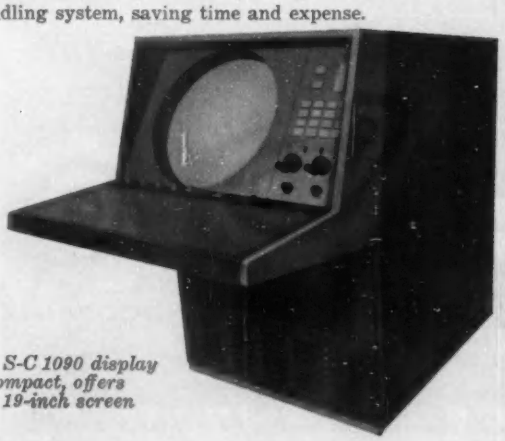
First "off-the-shelf" high resolution display for low cost computer monitoring

General Dynamics/Electronics' new S-C 1090 is the first "off-the-shelf" computer display featuring high character legibility on a large CRT screen. The S-C 1090 incorporates an improved 19-inch CHARACTRON® Shaped-Beam Tube and is capable of displaying 1000 flicker-free, high-resolution characters simultaneously anywhere on the tube face. Thirty thousand or more characters per second may be displayed with extreme brightness and contrast.

MOST VERSATILE DISPLAY. The S-C 1090, operating either on-line or off-line, is designed to monitor digital computer systems and present data for decision or information purposes. Alphanumeric or symbolic characters, and vectors may be presented singly or in combination.

Maximum flexibility for various applications has been provided by a number of special modular optional features for the S-C 1090 display which include:

1. *Internal Test Pattern Generator*—permits complete set up and calibration without tying up the computer or data handling system, saving time and expense.



The S-C 1090 display is compact, offers full 19-inch screen

2. *Vector Generator*—capable of drawing straight lines between points on the tube for graphic presentations.

3. *Format Generator*—reduces the S-C 1090's input requirements and doubles display rate from computer.

4. *Input Register*—provides console with buffer storage for position and character selection information.

5. *Offset & Expansion*—can enlarge any segment of tube screen to full screen size for more detailed view.

6. *Category and Feature Select*—allows selection of information for display without computer intervention.

SUPERIOR CHARACTER FORMATION. The CHARACTRON tube's unique method of shaped-beam character formation offers proven advantages over less precise line-segment, dot, or scan character forming techniques.

Symbols and characters are obtained by extruding electron beams through stencilled openings in a metal disc called the matrix. After passing through the matrix, the character-shaped beam is directed to an appropriate spot on the tube face. Most matrix have 64 characters.

COMPACT DESIGN. The S-C 1090 is a compact unit measuring 32 inches in width, 45 inches in height, by 66 inches in length. The unit's low silhouette allows operators to actually look over the top of the console for simultaneous viewing of the tube screen and projected large screen displays.

S-C 1090 APPLICATIONS. The S-C 1090 is capable of tabular, situation or graphical presentations and can be used in a wide range of computer intervention, monitoring and retrieval jobs. It is suitable for laboratory, simulation, Air Traffic Control and surveillance applications.

For additional information on the S-C 1090 Direct View Display or other General Dynamics/Electronics readout and display systems, write General Dynamics/Electronics, Information Technology Division, Dept. B-49, P. O. Box 2449, San Diego 12, Calif.

GD

GENERAL DYNAMICS | ELECTRONICS

CIRCLE 63 ON READER SERVICE CARD 63

PLENTY OF PUSH in a small package



STRIPPIT HYDRA SPRINGS DELIVER 600% MORE FORCE



STRIPPIT Hydra Springs, using compressible liquids, develop up to 600% more force than mechanical springs of comparable size. Six standard models develop forces from 2,200 lbs. to 8,500 lbs. and operate with strokes ranging from ¼" to 1½". Spring rates run from 2,200 lbs. to 32,000 lbs./in.



STRIPPIT Hydra Springs' high spring force, instant action and compact size make them ideal components in many installations where space is at a premium. Typical applications include uses with dies, perforating equipment, machine tools and plastic injection dies, cable tensioning devices, retarding mechanisms.



STRIPPIT Hydra Springs use STRIPPIT Comproils. Changes in the type or volume of Comproils vary and adjust the loads of the Hydra Springs to meet required forces of individual applications. In addition, a force adjuster for critical pressure adjustments is provided on all Hydra Springs except Model 38K11.



STRIPPIT Hydra Spring applications are so varied that, in addition to the standard models, STRIPPIT's engineers can custom design and fabricate special Hydra Springs to solve your problem. A call to your STRIPPIT Tool & Methods Engineer will bring immediate help. If you prefer, write for Catalog K.

WALES **STRIPPIT** INC.

A UNIT OF HOUDAILLE INDUSTRIES, INC.

259 Buell Road • Akron, New York

In Canada: Strippit Tool & Machine Company, Brampton, Ontario

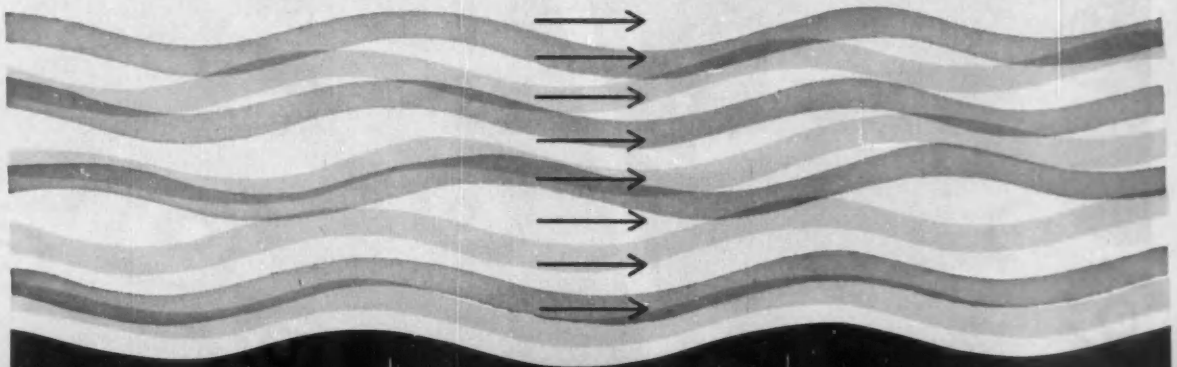
In Continental Europe: Raskin, S. A., Lausanne, Switzerland *In the British Isles: Kearney & Trecker—C. V. A. Ltd., Hove, Sussex, England*

Honeywell announces the NEW series 1400 low flow control valve

The addition of the new Series 1400 valve body to the Honeywell line of control valves now gives you a choice of actuator-body combinations to match your applications. Now you can choose the exact type and degree of control you need, without pushing a valve beyond its design limits . . . or without paying for more performance than you need.

The compact Series 1400 valve body is available in a full range of materials, ratings and sizes, with screwed or flanged ends. It can be used to regulate small flows in process, pilot plant, research and commercial control systems. Each body size (½", ¾" and 1") has a wide range of reduced ports with Cv's from .025 to 11.0. Two bonnet constructions facilitate mounting of five types of actuators —three pneumatic and two electric.

Each actuator-body combination fits a different range of operating conditions and performance characteristics, but with sufficient overlapping of these ranges to give you a wider selection on the basis of cost. For complete details, write for Bulletin B803-1. MINNEAPOLIS-HONEYWELL, Fort Washington, Pa.





Model 1401 Low Flow Valve with heavy-duty pneumatic actuator for systems requiring high shut-off ratings and accurate valve positioning.



Model 1403 Low Flow Valve with compact, light weight pneumatic actuator for average industrial and commercial control systems.



Model 1404 Low Flow Valve with reduced port Cv's to .025 and top-mounted positioner integral with pneumatic actuator.



Model 1406 Low Flow Valve with *Modutrol* capacitor-type, electric motor actuator for two-position, floating or proportional control.



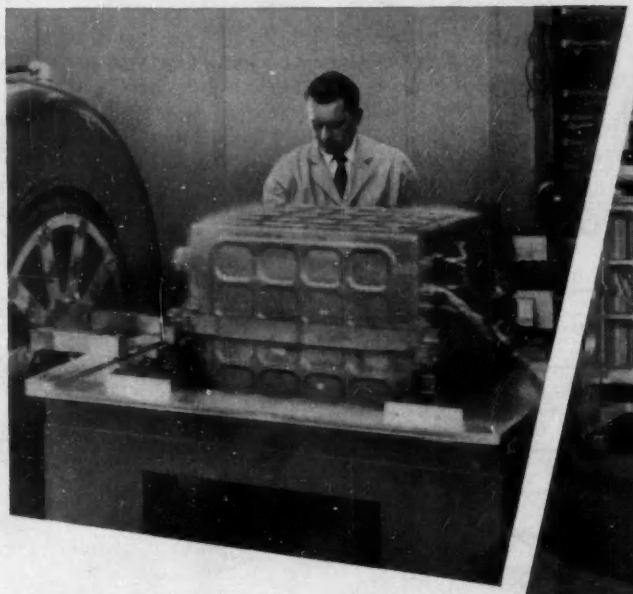
Model 1407 Low Flow Valve with heavy-duty *Actionator* electric motor actuator provides more power for higher valve shutoff ratings.

Honeywell

H First in Control

HONEYWELL INTERNATIONAL Sales and Service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

ARMA SYSTEMS





Vibration exciters, precision centrifuges—these are among Arma environmental test facilities used to subject weapons systems to performances far beyond actual operation—to assure reliability, accuracy and long service life.

predictable by test...proved by performance

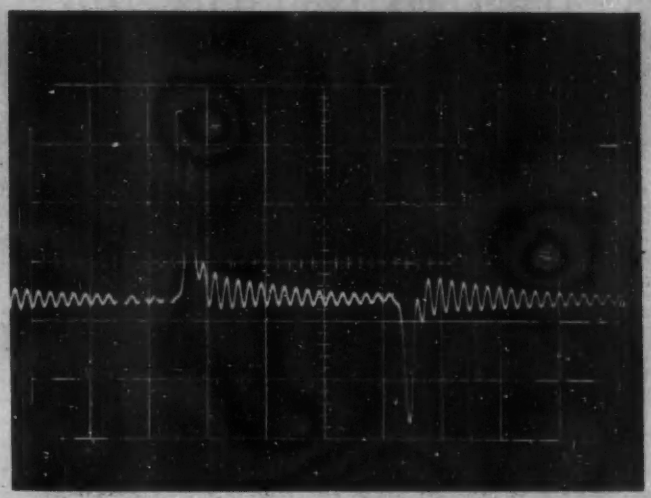
In the receiving areas, in the materials test laboratory, on the production lines, in assembly and at the final test station . . . wherever you look in the Arma plant you'll see quality control and inspection equipment in use. Here rests the responsibility for maintaining the reliability of Arma systems.

And, Arma systems are famous for reliability: All-inertial guidance for the Atlas ICBM, a proved system of intercontinental range accuracy . . . the defense system for the B-52 . . . shipboard fire control and navigation systems . . . anti-submarine warfare systems.

Arma's chief contribution to our national defense effort is the ability to deliver reliable systems—on schedule and within the budget. All research and development, engineering and production are based on that philosophy. Arma, a division of American Bosch Arma Corporation, Garden City, New York.

2268

AMERICAN BOSCH ARMA CORPORATION



High resolution, distortion-free pictures just like this, and this same size, are yours immediately with the hp 196A Oscilloscope Camera plus new Polaroid® Land 10-second-developing, 3000 speed film



The hp 196A Oscilloscope Camera provides pictures as sharp and clear as the original CRT trace. The pictures are 9/10 full size (or full size, see Specifications), distortion free, "flat" and scalable. Multiple exposures, up to 11 traces per picture, are simple.

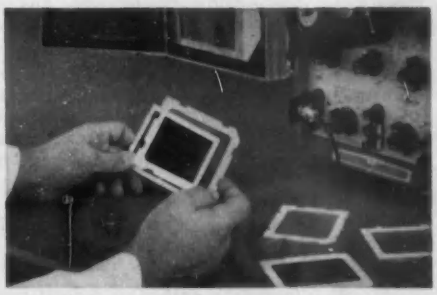
Polaroid Land films give you prints in 10 seconds, transparencies in two minutes. Resolution of the new 10 second film is 50% improved. Very fast Type 47 (ASA speed 3,000) Polaroid Land film can record the fastest transients. Its high sensitivity gives you better pictures from your oscilloscope. The picture above shows a single damped 10 MC sine wave photographed on this film in the hp 196A.

You can mount or dismount Model 196A with one hand; change f-stop and shutter settings with the camera on the scope; tab pulling is easy; and you can keep your glasses on while viewing the image with both eyes.

Check the specifications for the hp 196A Oscilloscope Camera and ask your hp representative for a demonstration on your scope!

SPECIFICATIONS

Object/Image Ratio:	1 to 0.9 (accessory, $25.00 extra, provides 1:1 ratio)
Lens:	Wollensak 3" (75 mm) f/1.9 Oscillo-Raptar
Lens Opening:	f/1.9 to f/16
Shutter:	Alpha #3. Time, 1/100 to 1 second
Print Size:	3¼" x 4¼" image area 2⅞" x 3 - 13/16"
Film:	Polaroid® Land Types 42, 44, 46, 46-L, 47.
Price:	$440.00



Slides For Projection can be Produced in Minutes. Black and white transparencies of oscilloscope traces in standard 3¼" x 4¼", lantern slide size, are instantly ready for projection with Polaroid Land Film, type 46L.



Polaroid transparencies (ready in 2 minutes) from your hp 196A can be attached to typewritten repro masters of a report for distribution within the plant. They are easily reproduced in one pass through a diazotype machine (Bruning, Ozalid, Technifax, etc.).

HEWLETT-PACKARD COMPANY

1060H Page Mill Road Palo Alto, California, U.S.A.
Cable "HEWPACK" DAvenport 6-7000

Sales representatives in all principal areas

Write direct for new, illustrated booklet on oscilloscope photography

Polaroid® by Polaroid Corp., Cambridge, Mass.

New GE 3101 DATA ACCUMULATION and COMMUNICATION system...

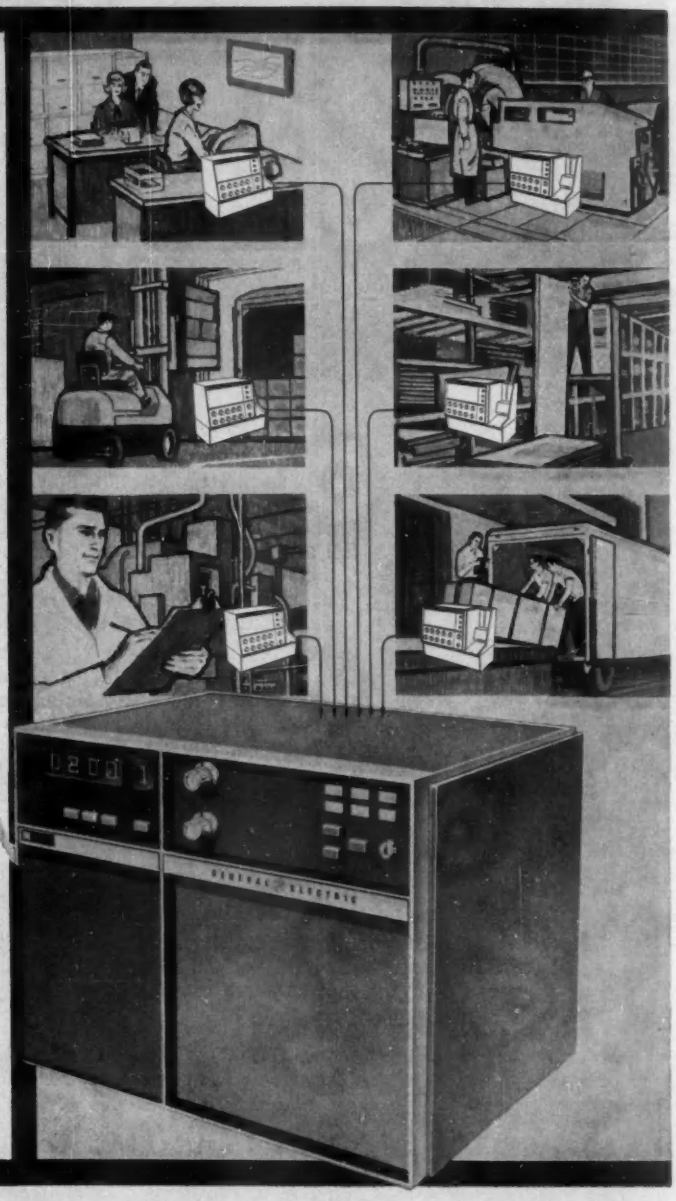
...provides immediate plant/ office data communication ...as a management tool to increase production and reduce costs.

The GE 3101 is General Electric's answer to the need for an economical and effective means of collecting operational data. Key areas such as purchasing, receiving, quality control, shop operations, warehouse, shipping, etc., send current data to a central point for collection and display. Each of the key areas has a Collector that sends data to the Accumulator, where it is punched into paper tape for a permanent record. Data originating at the Collector is from punched cards and/or 19 variable dial settings. Collectors may be up to 10,000 feet from the Accumulator.

The punched paper tape can produce a typewritten copy immediately for visual display of current conditions; can be converted to punched cards; or can be used for direct input to a computer system. Investigate this new, lower cost development by General Electric.

Installation of the GE 3101 information gathering system can result in greater operational profits due to: accuracy and timeliness of data, economy of operation, and quicker access to the facts for well informed decisions by management.

For more information, write for brochure CPB-183, General Electric Company, Computer Department, Section 92G9, Phoenix, Arizona, or contact your nearest General Electric Computer Department District Office listed below.



Atlanta: 270 Peachtree St. N.W., 522-1611 • **Boston:** 140 Federal St., HU 2-1800, Ext. 311 • **Chicago:** 120 S. La Salle St., 782-5061 • **Cleveland:** Williamson Bldg., 215 Euclid Ave., SU 1-6822 • **Dallas:** 3200 Maple Ave., RI 8-0589 • **Detroit:** 680 Antoinette St., TR 2-2600 • **Houston:** 4219 Richmond Ave., MO 7-3301 • **Kansas City, Mo.:** 106 W. 14th St., GR 1-2919 or GR 1-2920 • **Los Angeles:** 1010 S. Flower St., DU 1-3641 • **Louisville:** Bldg. 6, Appliance Pk., GL 4-7511 • **Minneapolis:** Plymouth Bldg., 6th & Hennepin, FE 2-7569 • **New York:** 122 E. 42nd St., PL 1-1311, Ext. 3205 • **Philadelphia:** 3 Penn Center Plaza, LO 8-1800 • **Phoenix:** Guaranty Bank Bldg., 3550 N. Central Ave., AM 4-3741-2 • **Pittsburgh:** 1634 Oliver Bldg., Mellon Sq., AT 1-6400, Ext. 566 • **San Francisco:** The Russ Bldg., 235 Montgomery St., DO 2-3740 • **Schenectady:** Bldg. 2, 1 River Rd., FR 4-2211, Ext. 5-4405 • **Seattle:** Dexter Horton Bldg., 710 Second Ave., MA 4-8300 • **St. Louis:** Paul Brown Bldg., 818 Olive St., GE 6-4343 • **Syracuse:** 1010 James St., GR 6-4411, Ext. 6141 or 6142 • **Washington, D.C. Area:** 7401 Wisconsin Ave., Suite 514, Bethesda, Md., OL 2-8100 • **In Canada:** Canadian General Electric Co., Ltd., Electronic Equipment and Tube Dept., 830 Lansdowne Ave., Toronto, Ontario, Canada. **Outside U.S.A. and Canada:** Producer Goods Export Department, International General Electric Company Division, 150 E. 42nd St., New York City, N.Y., U.S.A.

INFORMATION PROCESSING AUTOMATED BY GENERAL ELECTRIC

Progress Is Our Most Important Product

GENERAL ELECTRIC

CPA 92 (9-61)



Straight-Line Temperature Control

with Thermo Electronic Proportional Controller

Used with a conventional Self-Balancing Recorder or Indicator, and a transmitting slide-wire, the Thermo Electronic Proportional Controller functions as a time-proportioning device. It combines high performance and operating simplicity at a lower initial investment. Outstanding Features include . . .

Minimum Overshoot – Sensitive and continuous adjustment of control action as the set-point is approached prevents overshoot. Your processes are rapidly brought to set-point and closely maintained.

Minimum Cycling – Cycling is almost imperceptible, and since proportional action is limited to the low side of the set-point, "Hunting" or wild oscillation is eliminated. Recordings of your processes will appear to show "Straight Line Action."

Simplified Operation – Only two, non-critical adjustments are necessary – the proportional band and the load range. The conventional, highly critical, reset function adjustment has been eliminated. 100% proportional band adjustment provides widest control action.

Wide Application – Any process using on-off or high-low temperature control is accurately regulated with this Proportional Controller. These include electric furnaces, band or zone heaters on plastic extruders, solenoid valves, and others. The instrument can directly actuate control devices, or can be used to actuate a load relay.

High Accuracy – Electrical accuracy is ¼ of 1% of controller span, as related to accuracy of primary instrument.

The Thermo Electronic Proportional Controller is a unique concept in design for instruments of this type.

WRITE TODAY FOR YOUR 4-PAGE BULLETIN 53-11 .

Thermo Electric

Temperature Measuring Systems and Components

20 YEARS

THERMO ELECTRIC Co., Inc., Saddle Brook, New Jersey
In Canada: THERMO ELECTRIC (Canada) LTD., Brampton, Ont.

CIRCLE 69 ON READER SERVICE CARD 69


Son, we call this
a "Fisher"

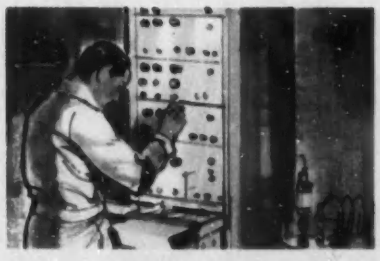
The worthiness of a name

In refineries, chemical plants, and oil fields, many "old timers" associate the name "Fisher" with high quality control valves and liquid level controllers. Through the years, in their work on instruments and controls, they have come to know that "Fisher" means dependability.

"Put a 'Fisher' in the line, and forget it." they would always say.

The quality found in Fisher equipment lies not only in metal and fiber and paint. It is also found in the practical design, manufacturing techniques, and the rigid inspection program. These high quality factors along with outstanding research and engineering facilities assure you of trouble-free performance. Throughout the world, "Fisher" means dependable control equipment.

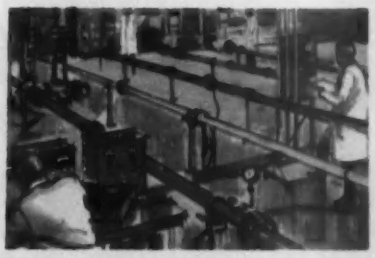
FISHER GOVERNOR COMPANY *Marshalltown, Iowa / Woodstock, Ontario / Rochester, England*



Continuous Advanced Research . . . Fisher research maintains a continuous program for development and use of new metals and materials to meet the increasingly severe conditions, encountered daily, in the nuclear and cryogenics fields.



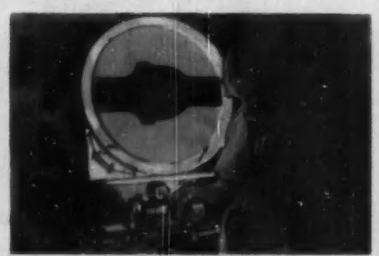
Engineering and Research . . . Almost three-fourths of Fisher's 41 graduate engineers have more than 10 years service . . . a total of 380 years experience in design engineering aimed at solving industry's flow control problems, practically and efficiently.



Testing and Development . . . Representative of the very latest and finest in equipment that aids Fisher engineers in the development of new and improved products is the recent addition of a test line that is capable of handling air or water pressures up to 2,500 psi.



Latest Production Methods . . . Various new style grinders produce a super-finish on Fisher valve guides and bushings, second to none in the industry. It is typical of precision manufacturing methods that assure long, trouble-free operation of Fisher controls.



Rigid Inspection Procedures . . . The highest ratio of inspection personnel to production personnel in the industry is maintained at Fisher. As an example, there are no less than 704 inspection operations on a 4" Type 657-A diaphragm control valve.



Efficient and Fast Service . . . "Supermarket" 36-hour delivery, from the factory, on popular sizes and types of controls is only one of many services available to Fisher customers. Seventeen sales offices throughout the country maintain field stocks for immediate delivery.

If it flows through pipe anywhere in the world ...chances are it's controlled by.....

FISHER®
Control
SINCE 1880

When you see this sign . . .

YOU'RE THE BOSS

That's right, you, the reader, are the boss of the publications you read. You, as a paid subscriber, are the customer who must be satisfied with these publications—their success depends on your continued readership.

When you pay for your subscription to a publication, you are actually controlling two multi-billion dollar industries: publishing and advertising.

The ABC Emblem on our masthead identifies CONTROL ENGINEERING as a member of the Audit Bureau of Circulations, an independent, non-profit association of publishers, advertisers and advertising agencies that regularly audits our circulation records and verifies our circulation statements. This is important to YOU because:

A The ABC circulation statement shows our editors who reads CONTROL ENGINEERING—what industries these readers are in and what types of jobs they hold. The more our editors know about *you*, a reader, the better equipped they are to provide the kind of instrumentation and control systems information and help for which you are willing to pay. Your renewal subscription (reported in the ABC Statement) is the editors' feedback on how well they are serving you.

B The facts reported in the ABC circulation statement help us describe you and our 31,800 other readers to our advertisers and prospective advertisers. This is vital to you because without advertising CONTROL ENGINEERING would either have to increase the subscription price to cover all the publishing costs, or reduce the editorial service you are now getting.

C The ABC statement provides advertisers with information they can use in determining both the products and the advertising message that will best serve your needs and interests.

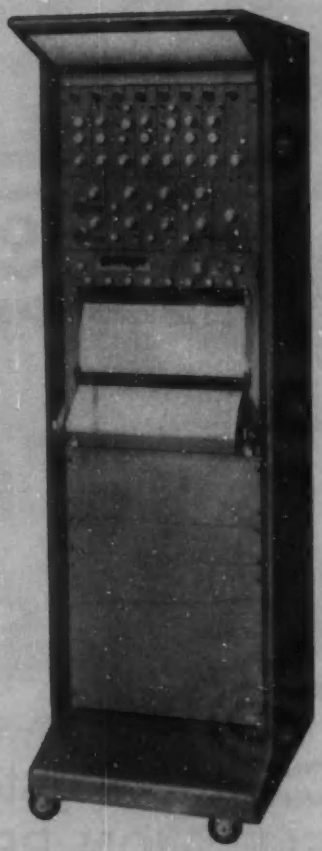
CONTROL ENGINEERING is proud to be a member of the Audit Bureau of Circulations (just as all McGraw-Hill publications are). The ABC emblem indicates that you, our readers, have the final say in our success. It is evidence of our respect for your trust—and of our whole-hearted efforts to live up to our primary obligation to you—our subscribers.

CONTROL ENGINEERING
A McGraw-Hill Publication

←CIRCLE 71 ON READER SERVICE CARD

TYPE

THE OFFNER R DYNOGRAPH



The most versatile and sensitive direct-writing unit available!

Ink, heat, electric recording media!

Handles all your recording requirements.

SILVER ANNIVERSARY

1936 1961

25 YEARS

OFFNER DIRECT-WRITING OSCILLOGRAPHS

25 years ago Offner invented the world's first Direct-Writing Oscillograph.

This *one* high-speed direct writing assembly handles *all* your recording requirements. You change only the input coupler for thermocouples, strain gages, servo monitors; for industrial, scientific, and medical applications.

☆ From one microvolt, d-c to over 200 cps.

☆ Ink, heat, electric recording media—easily convertible.

Write for complete details.



16 pages of facts, figures, and specifications on the Offner Type R Dynograph.

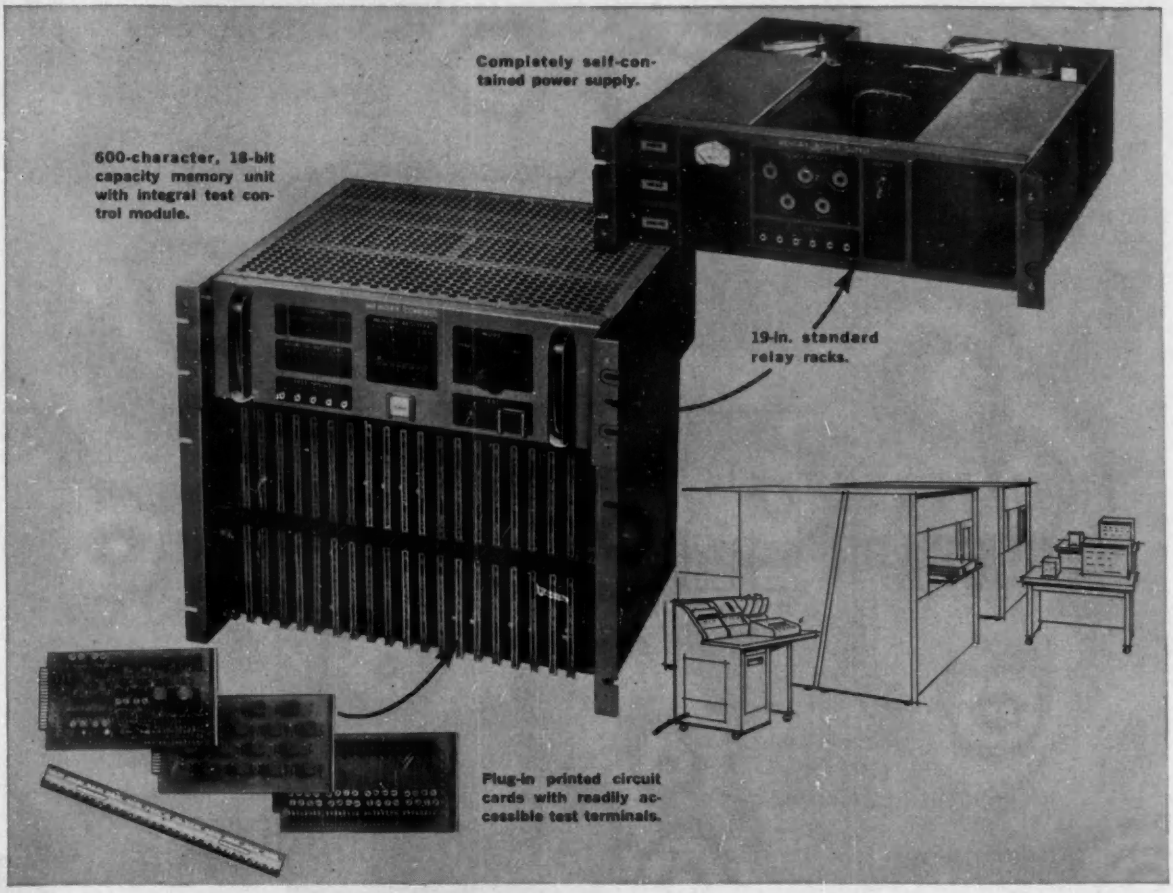
Write for your copy.

OFFNER ELECTRONICS INC.

3900 River Road, Schiller Park, Ill.
(Suburb of Chicago)

CIRCLE 73 ON READER SERVICE CARD

From General Ceramics Division of
INDIANA GENERAL CORPORATION



Compact GC Memory System Helps Norden Achieve **INSTANT ELECTION RETURNS...ERROR-FREE**

A General Ceramics modular-built memory package was selected by Norden Division of United Aircraft Corporation for its new Electronic Vote Tallying System, which will speed election returns in Los Angeles County, California.

This remarkable system can tally 10 hand-marked paper ballots every second — providing complete election results from an average Los Angeles precinct in less than a minute.

According to Jerome Nishball, Norden Project Engineer, "GC's memory system was chosen primarily because of the compactness of design which permitted us to reduce the *overall size* of our electronic equipment by 20 percent — this saving alone was significant even without considering GC's very competitive price."

Mr. Nishball went on to say — "The GC memory was subjected to and passed required operational and environmental tests — and it's been performing as expected ever since."

Let us show *you* how our modular design concept using standardized circuitry and in-stock modules can speed deliveries of custom memory systems while improving reliability, cutting space requirements, and simplifying maintenance. Ask for Bulletin 26.

DIVISION OF INDIANA GENERAL CORPORATION

APPLIED LOGICS DEPARTMENT

GENERAL CERAMICS

Phone VAlley 6-5100 • Direct Distance Dialing Code 201

KEASBEY, NEW JERSEY, U.S.A.

TECHNICAL CERAMICS, FERRITES AND MEMORY PRODUCTS

New Bourns Precision Potentiometer Resolves the Quality-Price Dilemma!

NUMBER 18—NEW PRODUCT SERIES

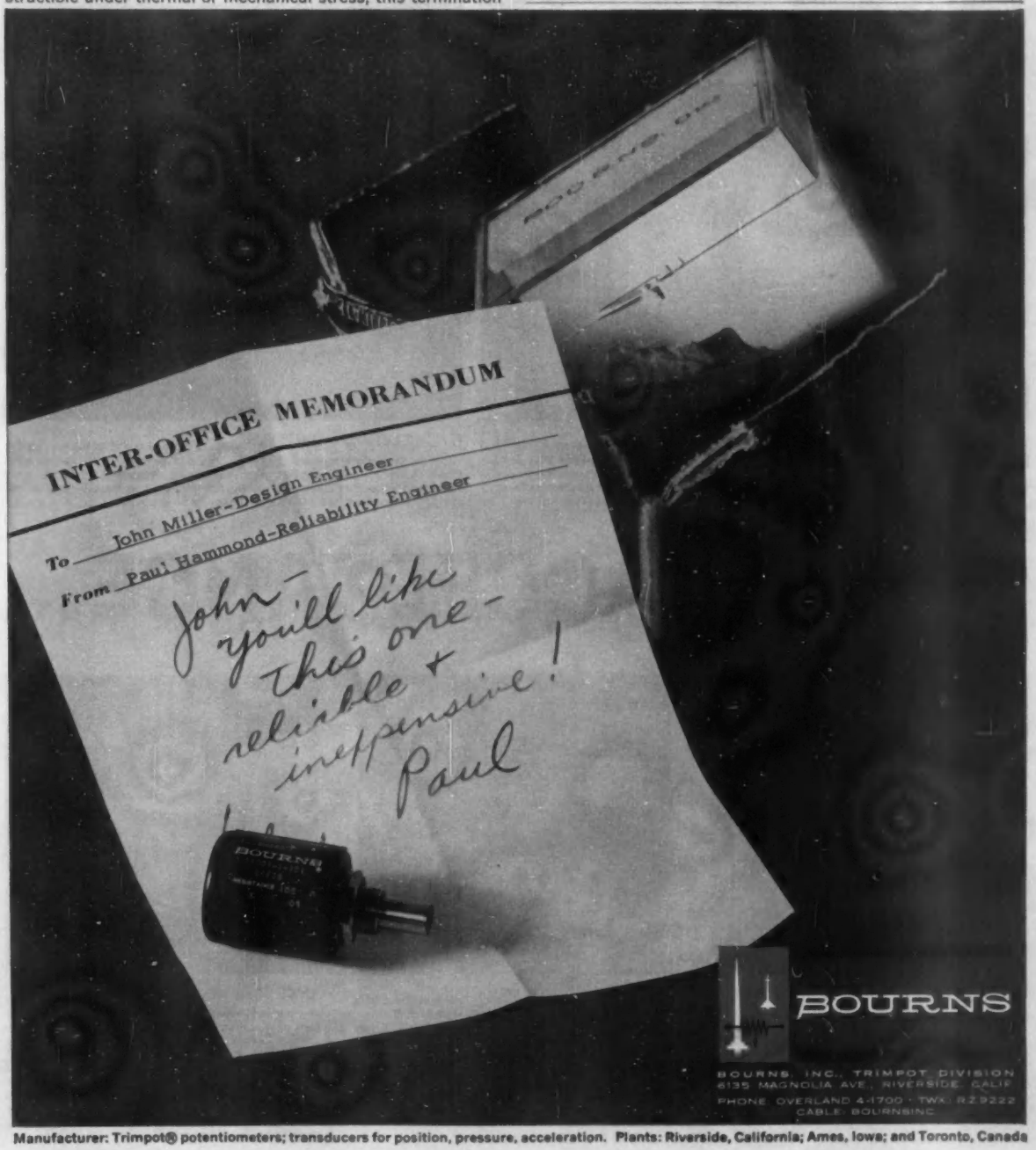
Here is military reliability in a competitively-priced industrial potentiometer. Bourns wirewound 10-turn Model 3500 measures just ⅞" in diameter by 1" long—shorter by ½" than units available elsewhere—yet has a resistance element 20% longer than that of comparable potentiometers.

Fully meeting military requirements for steady-state humidity, Model 3500 can also be provided at a 10% premium to meet the cycling humidity specs of MIL-STD-202, Method 106. It's the only ⅞" 10-turn potentiometer guaranteed to meet this spec. Its published characteristics incorporate wide safety margins.

Reliability insurance is provided by the exclusive Bourns Silverweld® bond between terminal and resistance wire. Virtually indestructible under thermal or mechanical stress, this termination eliminates a chief cause of potentiometer failure. In addition, a special close-tolerance rotor almost completely does away with backlash.

Model 3500 is also subjected to the rigorous double-check of Bourns' exclusive Reliability Assurance Program. In short, every possible step is taken to ensure that the performance you specify is the performance you get. Write for complete data.

Resistances	500Ω to 125K, ±3%, std. (to 250K spl.)
Linearity	±0.25% std.
Power rating	2w at 70°C
Operating temp.	−65° to +125°C
Mech. life	2,000,000 shaft revolutions



BOURNS, INC., TRIMPOT DIVISION
6135 MAGNOLIA AVE., RIVERSIDE, CALIF.
PHONE OVERLAND 4-1700 · TWX: RV 9222
CABLE: BOURNSINC

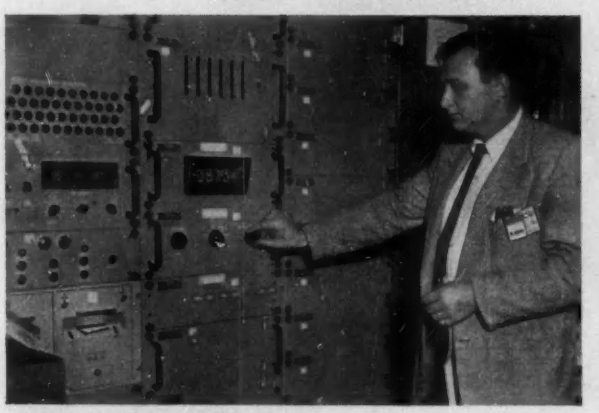
Manufacturer: Trimpot® potentiometers; transducers for position, pressure, acceleration. Plants: Riverside, California; Ames, Iowa; and Toronto, Canada



FINAL PRODUCTION TESTING. Zener diodes are checked by NLS M24s at final testing stations of Hughes Aircraft Company's Semiconductor Division.



CHECKOUT OF MISSILE COMPONENTS. An M24 checks electronic components at Autonetics, a division of North American Aviation, Inc., as part of the High Reliability Program for Minuteman ICBM. The operator is shown measuring resistance. By turning a front panel knob on the M24, she can also measure DC voltage or DC voltage ratio.



MISSILE PRODUCTION TESTING. An NLS M24 Multi-Purpose Instrument performs an important part in the missile functional test system at Boeing Airplane Company's Missile Production Center in Seattle, Wash. The system automatically applies more than 400 go/no-go sequenced tests to ground-check missile flight reactions from launch to intercept. The M24 and the printout portion of the system monitor application of test stimuli and isolate malfunctions.

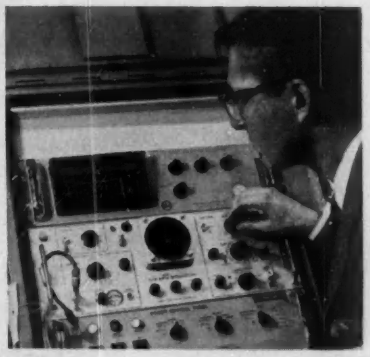


ELECTRO-CHEMICAL ANALYSIS. Savings of as much as $8,000 a year on one particular project are expected to result from use of an NLS 481 DVM at Diamond Alkali Company's plant in Deer Park, Texas. By accurately measuring small changes in voltage and voltage drop, it permits optimizing the efficiency of producing chlorine from sodium chloride brines by electrolysis.

ACCEPTANCE...



PETROLEUM RESEARCH AND DEVELOPMENT. This precision data logging system, incorporating an NLS V24 DVM, has served Esso Research Laboratories for more than two years in around-the-clock service. The V24 converts millivolt signals to digital form for operating a Friden Tape Punch. The system aids in making pilot plant studies of industrial processes.



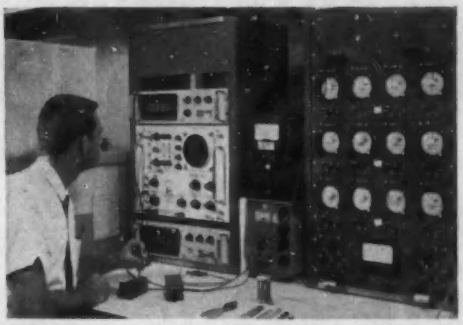
MISSILE TRACKING SYSTEMS. The Azusa Test Set, designed by General Dynamics/Astronautics, A Division of General Dynamics Corporation, includes an NLS V35 DVM. This set checks the power and transmitter portions of the airborne package of the system which is used for tracking all missiles launched from Cape Canaveral. Functions of the V35 include monitoring of 28-, 100- and 1,500-volt power supplies; calibrating telemeter transducers; and adjusting Klystron beam, bias and modulator voltages.



SPACE MEDICINE RESEARCH. In simulated space environment testing, this NLS V34 digital voltmeter is part of a system which detects and records minute changes in body weight, a key factor in determining physiological strain. The unique "No Needless Nines" logic of the V34 permits measurements at pre-selected time intervals with an accuracy of ± 3 grams within a range of $\pm 4{,}500$ grams. AMF's Mechanics Research Division developed the overall system under direction of the Air Force's Aeronautic Systems Division at Wright-Patterson AFB in Ohio.



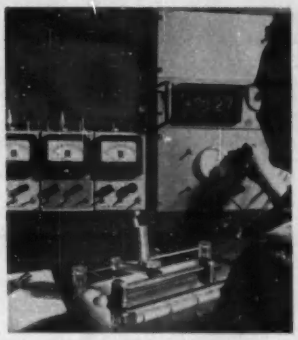
PRODUCTION TESTING. A 481—one of a battery of NLS DVMs—measures Zener diodes for separation into voltage categories at the Semiconductor Products Division of Motorola, Inc. Measuring speed for this operation was doubled by use of the NLS digital voltmeters.



MISSILE CHECKOUT. Two NLS DVMs team up on checkout of equipment for the GAM-77 Hound Dog Missile at the West Coast Laboratories of Mallory Electronics Company, A Division of P. R. Mallory & Co. Inc. The 481 (bottom) calibrates remotely settable timers for the Hound Dog and the V35 (top) is used for final checkout of these devices. "By using DVMs, we are able to eliminate human error in final inspection," said a Mallory executive.



QUALITY CONTROL OF ELECTRONIC COMPONENTS. More than 50 NLS 481 digital voltmeters are used in the Quality Assurance Program at the Semiconductor-Components Division of Texas Instruments Incorporated. The instrument pictured is measuring breakdown voltages of high-reliability germanium switching devices.



MATERIALS EVALUATION. Electronic Chemicals Division of Merck & Co., Inc., uses a 481 DVM to reduce testing time for determining resistivity of single crystal silicon.



A-TO-D CONVERSION IN INDUSTRIAL PROCESSING. A 481 DVM operates an analog-to-digital converter in a variance computer for Saran Wrap production at The Dow Chemical Company's Saran Wrap plant in Midland, Mich.

sign of superiority in digital voltmeters

If you measure or record voltage, consider the broadening applications of digital voltmeters as indicated by these examples. The NLS instruments shown here... and the thousands of others in action today... tell a story of acceptance that is three-fold:

1. The digital voltmeter—first unique instrument since the development of the oscilloscope and vacuum tube voltmeter—has become a *basic measuring and logging tool* since its origination by Non-Linear Systems, Inc., nine years ago.

2. NLS digital voltmeters have been *proved in use* by many of the most discriminating companies in the electronics and allied industries.

3. Most of these firms have *specified NLS again and again,* some owning more than fifty instruments... evidence of the acceptance of NLS, as well as the usefulness of the product it manufactures.

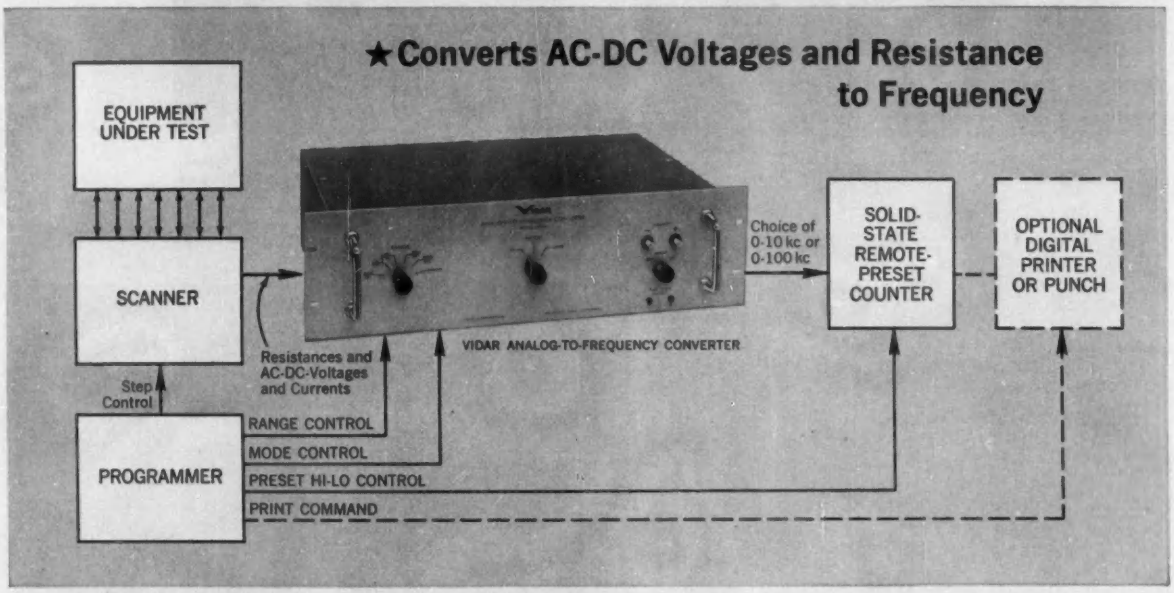
Our point: it makes sense to contact the most experienced manufacturer of digital voltmeters to meet your measuring and data logging needs. Select from the world's most complete line... by purpose... by price. NLS offers 16 basic models—all with exclusive features—from a low-cost "Industrial" type instrument to a $6,150 all-electronic DVM that makes 200 readings per second. For the most complete and authoritative information available on DVMs, contact your local NLS office or rep, or write NLS.

Visit Us At The Los Angeles ISA Show (Booth 105)

non-linear systems, inc. *Originator of the Digital Voltmeter*
DEL MAR, CALIFORNIA

Solid State Solution to Automatic Checkout

Announcing the VIDAR 2500 Analog-to-Frequency Converter



Missing link in applying digital techniques to automatic checkout has long been an accurate and flexible means of converting electrical parameters to digital form. The new Vidar 2500 closes the chain of measurement solidly, economically and reliably.

Combined with a counter, a Vidar 2500 analog to frequency converter provides direct digital readout of basic electrical parameters. Adding a printer makes a low cost digital data logger. Using a preset counter, the system becomes a go-no-go, hi-lo, in or out of limits tester. Remote control capability of the converter enables an external programmer to control its range and mode.

Applications for this kind of system include production checkout of components and systems, experimental data acquisition, component sorting, and quality control testing. As illustrated by the diagram, automated testing can be accomplished by combining an input scanner, Vidar converter, preset counter and printer with an automatic programmer which advances the scanner and printer, controls range and mode on the converter, and sets high and low limits on the counter.

Vidar 2500 converters develop output pulses at a rate precisely proportional to voltage or resistance. Almost any group of electrical parameters can be automatically checked with the basic low cost combination of a Vidar converter and an electronic counter. Other systems either require expensive digital comparators to do the same job or cannot read all the electrical parameters.

KEY TECHNICAL FEATURES

- Manual or Remote Range and Mode Selection
- Automatic Polarity Indication
- Full-Scale AC and DC Sensitivities from 0.1v to 1000v
- 1 K to 10 Meg Resistance Ranges
- Solid-State Circuitry—No Vacuum Tubes
- 0.1% Accuracy for DC and Resistance, 0.5% Accuracy for AC from 50 cps to 100kc
- Counted Output is Proportional to Integral of Input Giving Inherent Noise-Averaging Property.
- Choice of 0-10kc or 0-100kc Frequency Outputs
- Floating Input, Isolated from Rack and Output Grounds
- Low Cost—$1,500 to $2,500, depending on options

FOR A DEMONSTRATION
Call your nearby Vidar engineering representative or write directly to the factory for complete technical information.

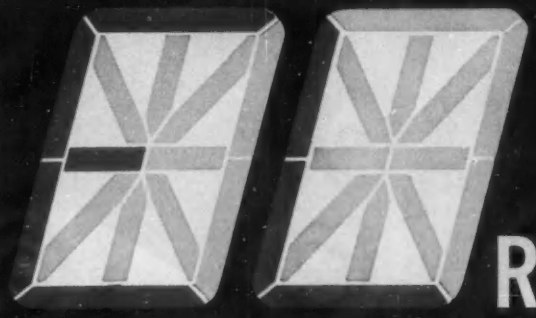
VIDAR CORPORATION
2296 Mora Drive
Mountain View, California
Phone: YOrkshire 8-6561

VIDAR ENGINEERING REPRESENTATIVES

ALABAMA, Huntsville, S. S. Lee Associates, Inc., JEfferson 6-0631 • **CALIFORNIA, Los Angeles (Beverly Hills),** Moxon Electronics Corp., BRadshaw 2-9311 • **CALIFORNIA, San Francisco (San Mateo),** Moxon Electronics Corp., FIreside 5-7961 • **CALIFORNIA, San Diego,** Moxon Electronics Corp., HUdson 8-2901 • **CONNECTICUT, Stratford,** Instrument Dynamics, Inc., DRexel 8-0435 • **FLORIDA, Orlando,** S. S. Lee Associates, Inc., CHerry 1-4445 • **ILLINOIS, Chicago,** Pivan Engineering Company, KE 9-4838 **INDIANA, Indianapolis,** Pivan Engineering Company, Victor 6-1532 • **MASSACHUSETTS, Boston (Wakefield),** Instrument Dynamics, Inc., CRystal 6-5100 • **NEW JERSEY, Ridgewood,** G. Curtis Engel & Assoc., GIlbert 4-1400 • **NEW YORK, Syracuse,** J. D. Ryerson Assoc., Gibson 6-1771 • **NEW YORK, New York City and Long Island,** G. Curtis Engel & Assoc., REctor 2-0001 • **NORTH CAROLINA, Winston-Salem,** S. S. Lee Associates, Inc., STate 8-0431 • **OHIO, Dayton,** Dayton Associates, BAldwin 3-9621 **PENNSYLVANIA, Philadelphia,** G. Curtis Engel & Assoc., WAlnut 2-3270 • **TEXAS, Houston,** Datronics, SUnset 2-0432 • **WASHINGTON, Seattle,** Comptronics, MAin 4-5135 **WASHINGTON, D.C. (Towson, Md.),** S. S. Lee Associates, Inc., LOckwood 5-3066

AVAILABLE NOW FROM SYLVANIA!

PANELESCENT®



Sylvania AN-150, 1½" alpha-numeric, is diagrammed, right, to show the 14 segments that produce the complete English alphabet, 0-9 numerics and selected mathematical symbols.

READOUTS

• NUMERICS, ALPHA-NUMERICS

... wide range of patterns, sizes, mountings

PANELESCENT electroluminescent (EL) devices open a vast new future for creative design of readout displays. Outstanding features include: compact, flat area source of light • long life • absence of catastrophic failures, enabling planned maintenance • low power requirements • wide angle viewing • simplified circuitry.

Sylvania advances in EL techniques now make practicable character heights from ⅜" for numerics and ⅝" for alpha-numerics to 12". Multiple numerics or alpha-numerics are available formed on one substrate for in-line display. Sylvania techniques of packaging can provide several "plug-in" designs, to conform with your individual design requirements, offering optimum combinations of economy, compactness and ruggedness.

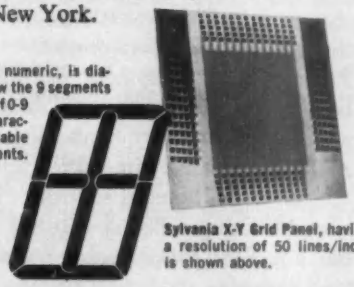
Sylvania X-Y Grid panels—for position-plotting displays—utilize conductive strips placed at right angles to each other. When the strips are excited a point of light is produced at the intersection. This point of light is moved by selective excitation of the strips.

• X-Y GRID PANELS

... wide range of sizes, resolutions

Sylvania X-Y panels, using a green phosphor, provide contrast ratios in the order of 15:1. Panels with active areas of 2½" x 2½" are now available with resolutions of as high as 50 lines/inch. Larger panels are also available.

Contact your nearest Sylvania Sales Engineering Office for further information. They'll be pleased to discuss your individual readout requirement. Or, send for the descriptive brochure, "Sylvania Electroluminescent Display Devices." Write Electronic Tubes Division, Sylvania Electric Products Inc., Dept. EL, 1100 Main St., Buffalo 9, New York.



Sylvania NU-150, 1½" numeric, is diagrammed, right, to show the 9 segments that produce a display of 0-9 numerics. Numeric characters are also available with as few as 7 segments.

Sylvania X-Y Grid Panel, having a resolution of 50 lines/inch, is shown above.

® Panelescent is a registered trade mark.

SYLVANIA

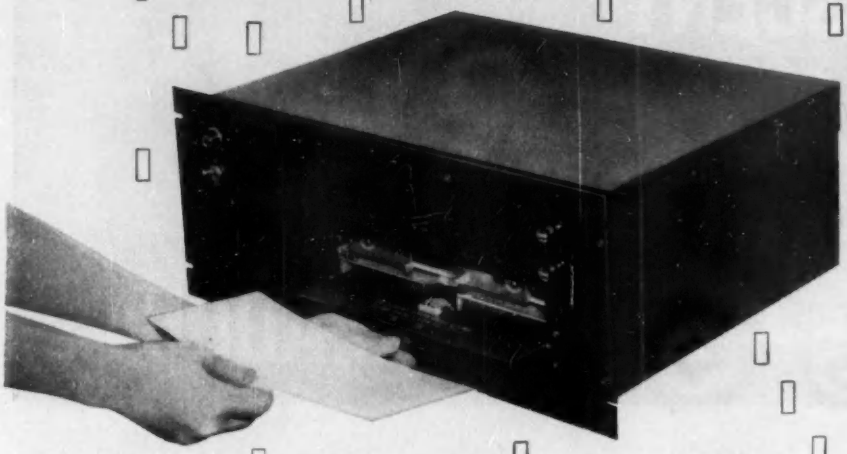
SUBSIDIARY OF

GENERAL TELEPHONE & ELECTRONICS

GENERAL SYSTEM

SIMPLE, RELIABLE

DIRECT CONTROL PROGRAMMING



INDUSTRIAL TIMER

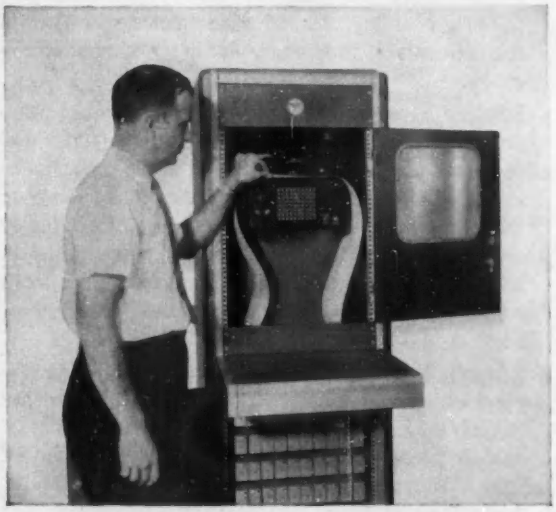
PUNCHED CARD AND PUNCHED TAPE

PROGRAMMING EQUIPMENT

Automatic equipment designed to provide direct control, without coding or decoding, for as many as 85 individual load circuits, through 30 or more different steps of an industrial process.

The Programmer is governed by a simple, punched vinyl card. The card or tape is advanced from position to position by a simple external switch closure signalled by feedback, time, limit switch, thermostat, and many others.

Programming equipment operated by punched tape is also available. Modular design permits addition of accessory banks of memory-type load relays. Industrial Timer Programmers are now in use for the automatic control of steel and aluminum blooming mills, structural steel fabrication, batching solid rocket fuels, and many other industrial processes.



Complete information in Bulletin 100, sent on request. Write or phone.

INDUSTRIAL TIMER CORPORATION

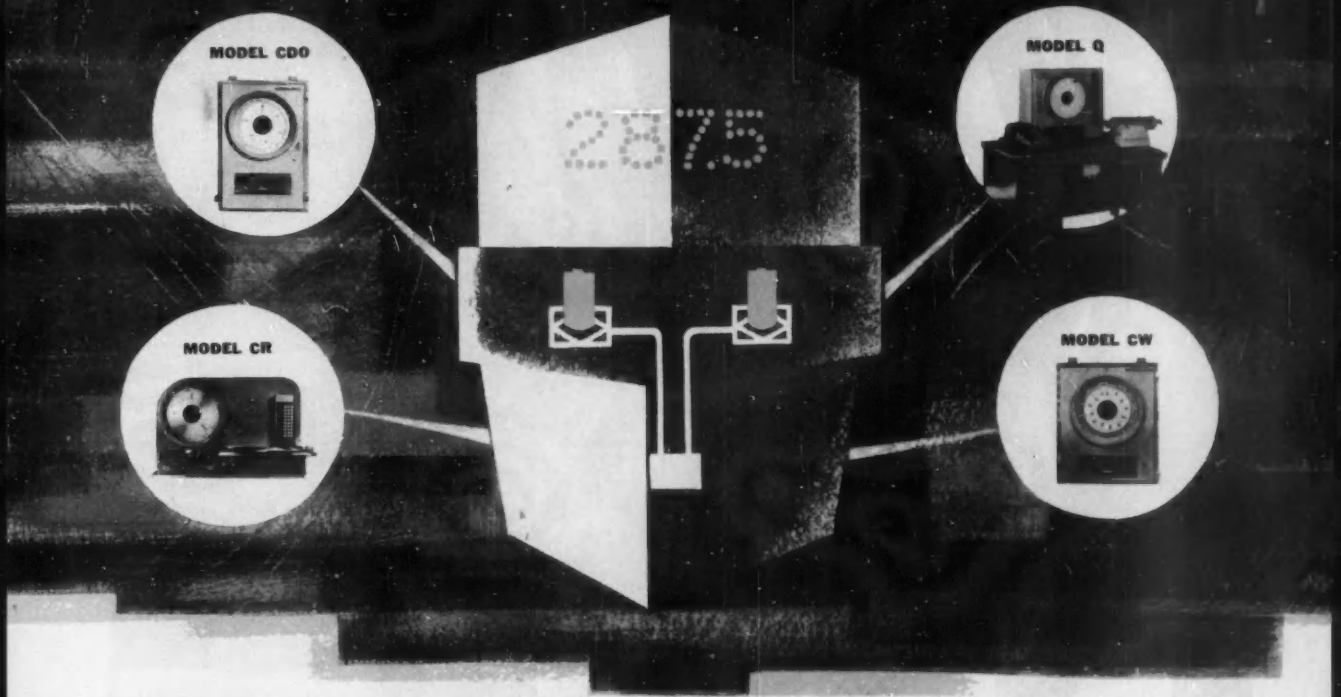
INDUSTRIAL TIMER CORPORATION

1401 McCarter Highway, Newark 4, New Jersey

Manufactured and sold in Canada by
SPERRY GYROSCOPE OTTAWA LIMITED • 3 Hamilton Ave., Ottawa, Canada • PA 8-4681

NOW FAIRBANKS-MORSE RECORDS WEIGHTS ELECTRONICALLY!

four F-M instruments solve weighing problems with greater speed...accuracy...flexibility



Four Fairbanks-Morse Electronic Weight indicating instruments, for use with an F-M Electronic Weighing System (either Full Electronic or Levetronic) enable you to choose the model that is best suited to your particular weighing needs. Each of these models offers fast, accurate weight indication. Each can be located up to 500 feet from the weighbridge.

Important features of these electronic weight indicating and recording devices are *automatic balance detection* (at true balance the instrument is automatically deactivated), *hold or memory circuit* (indicator can be held at last weight taken until a new weight is taken . . . is not forced to return to "zero"), *and automatic ranging* (an exclusive F-M feature that provides direct reading of weights. No mental calculations or mechanical manipulation are required. Original chart capacity is automatically expanded up to nine times).

There is a model for your particular needs:

MODEL CDO—For use where data processing equipment is used. Interprets weights and associated data, thus broadening the scope of work performed by all equipment.

MODEL Q—Provides the fastest weight indication of all F-M models. Ideal for your weighing-in-motion of single items in succession. Like the CDO, this model is for use where data processing equipment and office machines are used.

MODEL CR—A standard, table-mounted instrument with net-gross switch, selective "weigh" and "print" buttons, balance knob, direct-reading tare and standard printer.

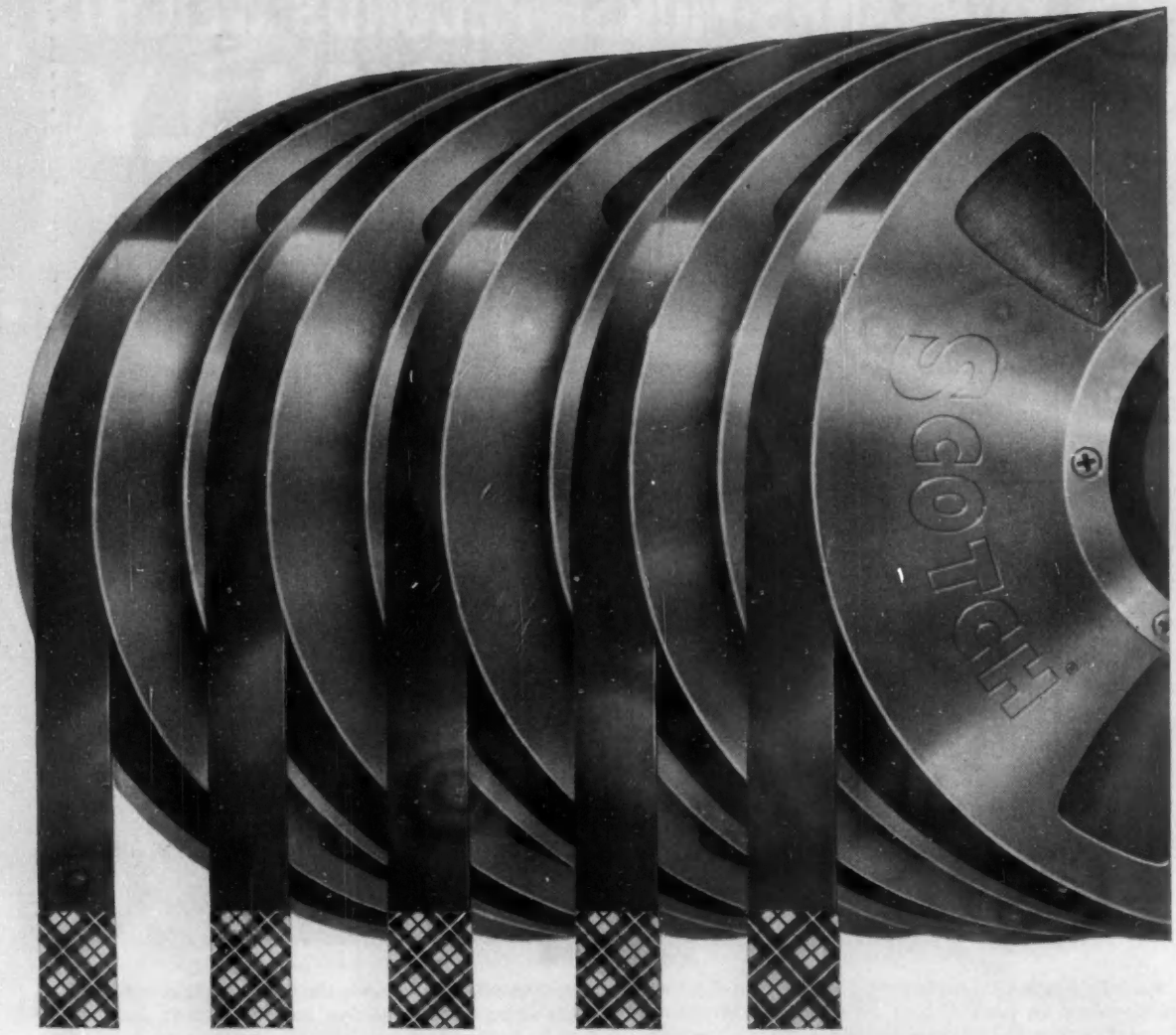
MODEL CW—Similar to Model CR except that this model is designed for uses where printing of the weights is not required.

Since weighing plays an important part in your operations, you should seriously investigate automating this often-neglected area. Automation with F-M electronic equipment offers the benefits of time, labor and material savings . . . important money savings that can add substantially to your profits.

For further information, write: Joe Peterson, Sales Manager, Electronic Weighing Department; Electronics Division; Fairbanks, Morse & Co.; 100 Electra Lane, East Station; Yonkers, New York.

ELECTRONICS DIVISION
FAIRBANKS MORSE
A MAJOR INDUSTRIAL COMPONENT OF
FAIRBANKS WHITNEY

CIRCLE 81 ON READER SERVICE CARD



SCOTCH® BRAND MAGNETIC INSTRUMENTATION TAPES
OFFER A RIGHT TAPE FOR EVERY APPLICATION

Knowledgeable tape users realize that magnetic tapes are not all alike—that it takes specific constructions to meet the needs of specific applications. And they've learned to rely on "SCOTCH" BRAND to supply the one right tape for each application. Not only does "SCOTCH" BRAND offer a complete line, it offers that something extra that makes all the difference in performance—the uniformity and reliability that result from 3M's experience, technical skill, and continuing research. Make the "SCOTCH" BRAND label your guide in buying instrumentation tapes. Your 3M Representative is close at hand in all major cities—a convenient source of supply and information. For details, consult him or write Magnetic Products Division, 3M Co., St. Paul 6, Minnesota.

© 1961, 3M Company

The wide "SCOTCH" BRAND line provides many tapes, including these broad classifications:

SANDWICH TAPES 488 and 489—exclusive with "SCOTCH" BRAND, offering 30 times the wear of standard tapes, drastic reductions in head wear, elimination of oxide rub-off. In standard or extra-play lengths.

HIGH RESOLUTION TAPES 458 and 459—offering superior resolution in high frequencies, greater pulse density in digital recording. In standard and extra-play lengths.

HEAVY DUTY TAPES 498 and 499—offering exceptional life, good resolution, high resistance to temperature and humidity, reduction in the build-up of static charge. In standard and extra-play lengths.

HIGH OUTPUT TAPE 428—offering top output in low frequencies. Performs well even in temperature extremes.

STANDARD TAPES 403 and 408—offering the good all-round performance at low relative cost which has made them the standards of the instrumentation field.

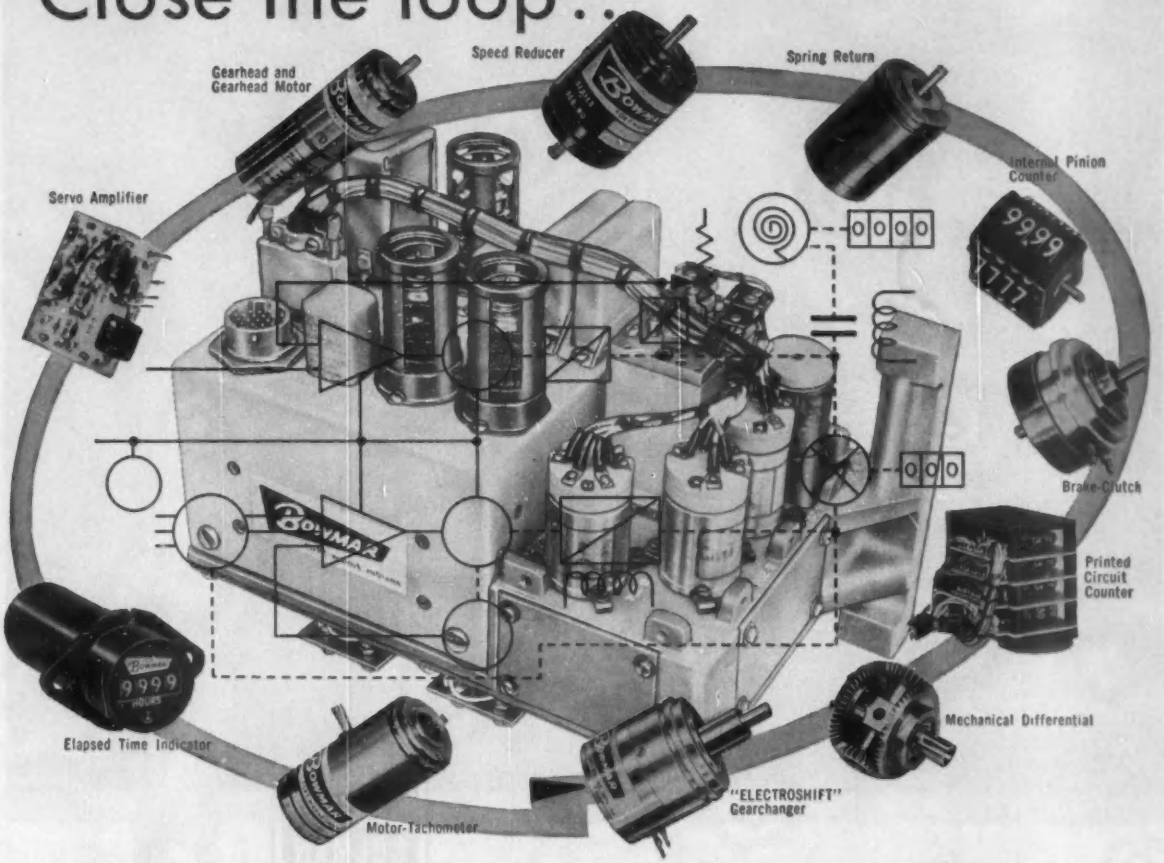
MINNESOTA MINING AND MANUFACTURING COMPANY
...WHERE RESEARCH IS THE KEY TO TOMORROW

3M COMPANY

"SCOTCH" BRAND MAGNETIC TAPES *FOR INSTRUMENTATION*

"SCOTCH" and the Plaid Design are registered trademarks of 3M Company, St. Paul 6, Minnesota. Export: 99 Park Avenue, New York, N.Y. In Canada: London, Ontario.

Close the loop..



buy the part or the package!

- **PRECISION MECHANICAL DEVICES**
- **PRECISION COUNTERS AND INDICATORS**
- **PRECISION TIMING AND PROGRAMMING DEVICES**
- **PRECISION ELECTROMECHANICAL DEVICES**
- **PRECISION SERVO PACKAGES**

You get "ONE STOP" capability in all phases of precision control and indication from Bowmar. This capability is available for design and production of all types of standard or specialized precision COMPONENTS. With equal facility Bowmar can engineer and integrate these devices into complete SERVO PACKAGES.

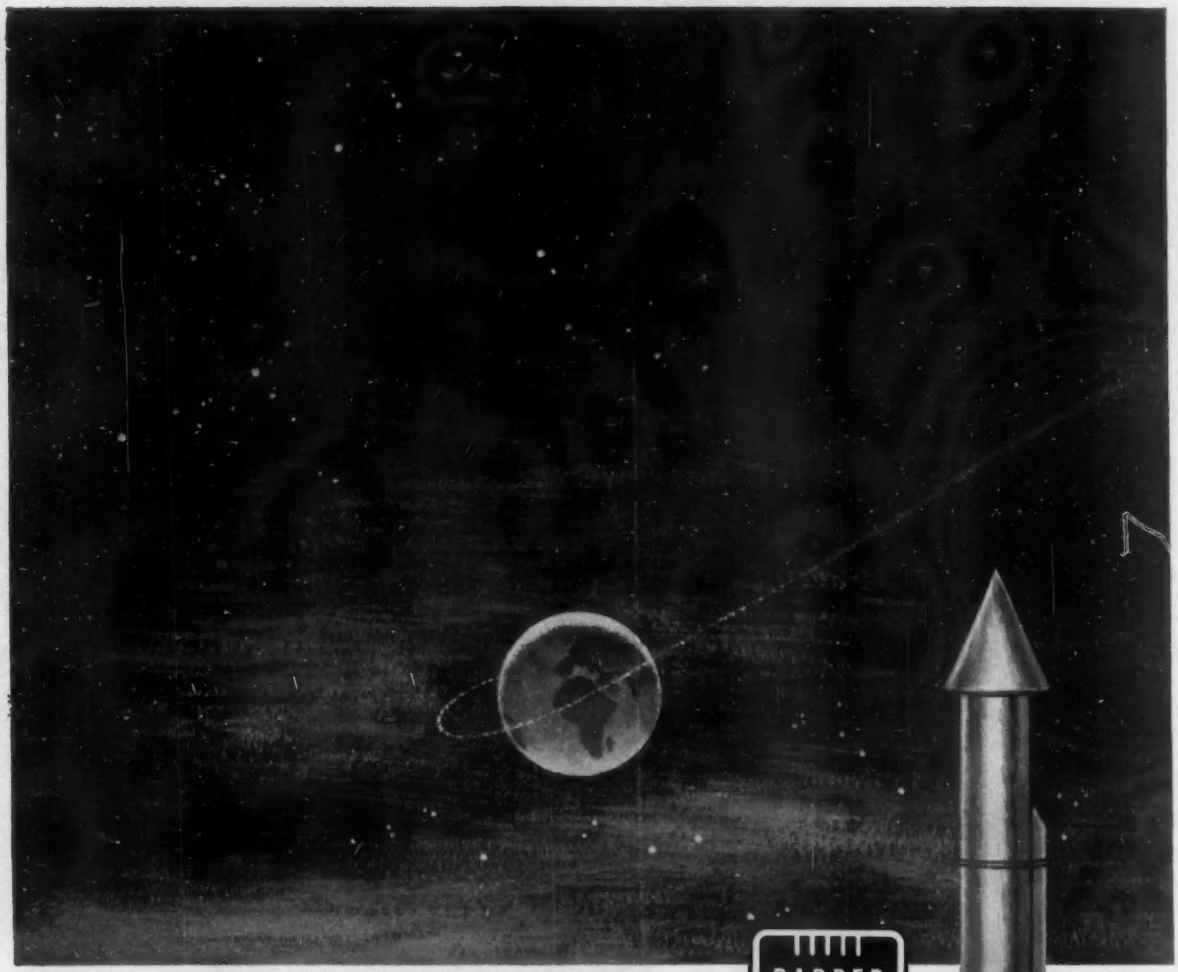
Inventive miniaturization, further weight reduction and increased reliability can be part of the benefits to your precision control or indicating systems.



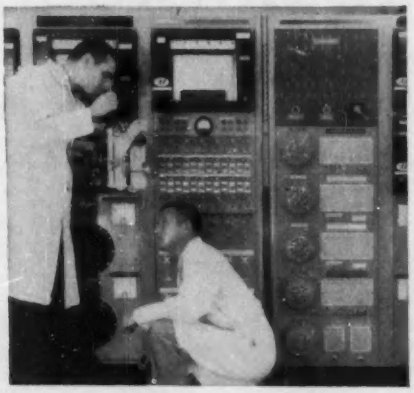
SEND FOR ILLUSTRATED PRODUCT FOLDER

INSTRUMENT CORPORATION
8000 Bluffton Road
Fort Wayne, Indiana
Telephone Sherwood 3121—TWX FW 296

CIRCLE 83 ON READER SERVICE CARD 83

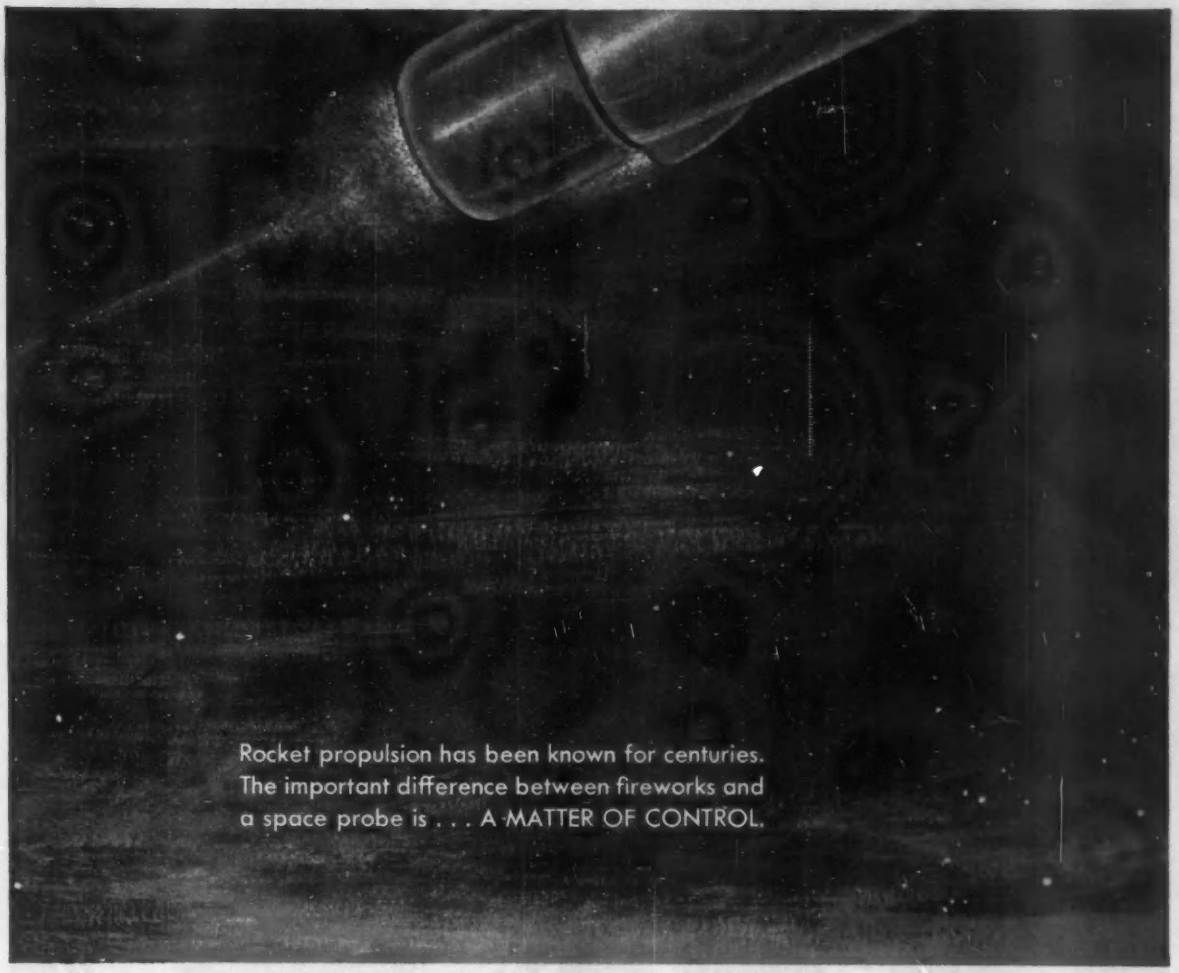


BARBER COLMAN



Atomics International, a Division of North American Aviation, Inc., designed this control system at Canoga Park, Cal. for testing nuclear fuels at the National Reactor Testing Station in Idaho. The panels monitor surface and center fuel temperatures and control a neutron absorbent for four fuel capsules simultaneously.

Industrial Instruments • Automatic Controls • Air Distribution Products • Aircraft Controls • Electrical Components



Process Control Systems . . .

To achieve an important difference in process control requires excellence in two areas. You must have good instruments and they must be integrated into a balanced, responsive, dependable system. Famed Barber-Colman industrial process control instruments engineered by trained field engineers assure excellence. Twenty-five years of process control application experience assures it, too. Call on Barber-Colman to insure the difference is in your favor.

Dept. Q, 1548 Rock Street
Rockford, Illinois, U.S.A.

Barber-Colman of Canada, Ltd.
Dept. Q, Toronto and Montreal
Export Agent:
Ad Auriema, Inc., N.Y.

BARBER-COLMAN COMPANY

Wheelco Industrial Instruments Division

Small Motors • OVERdoors and Operators • Molded Products • Metal Cutting Tools • Machine Tools • Textile Machinery

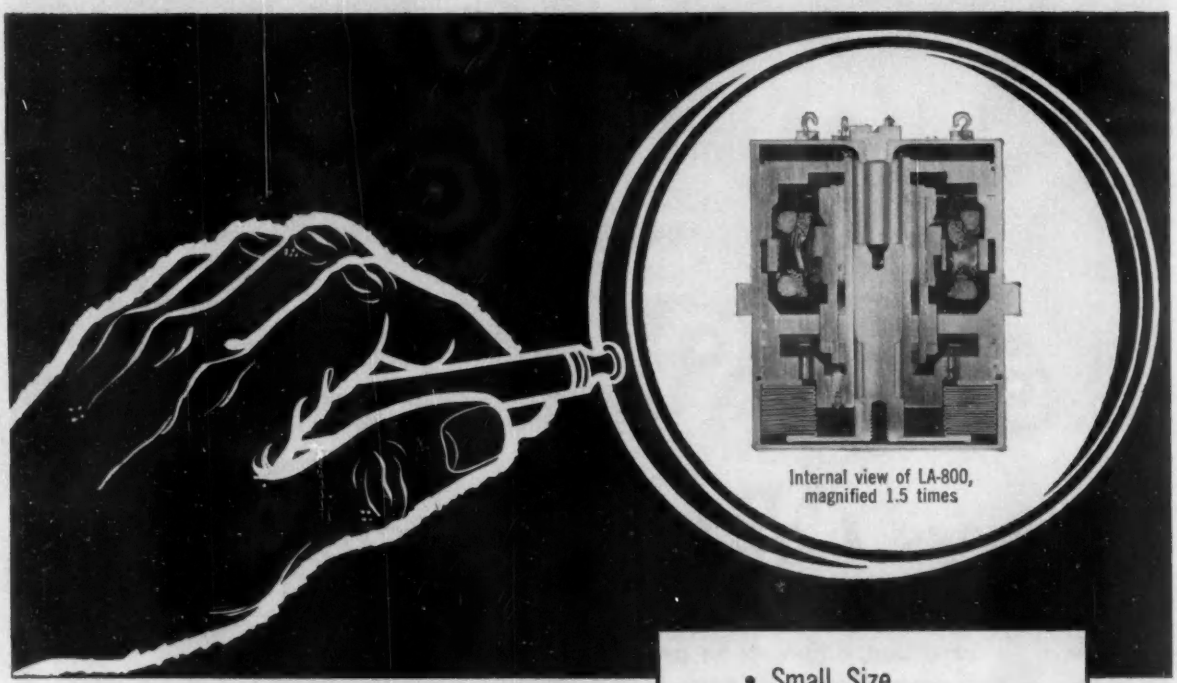
BIG ACCELEROMETER PERFORMANCE IN A SUBMINIATURE PACKAGE!

The LA-800 Series is the smallest non-pendulous linear accelerometer available today featuring a variable reluctance pickoff and essentially constant damping over the temperature range of −65°F to +250°F. It is the smallest instrument of its type that can measure acceleration forces up to 80 G.

Reliability through overall simplicity was the primary goal of the LA-800 design. An example is the seismic mass support which eliminates sleeve bearings and their inherent friction. The result of this basic design objective is an accelerometer which can be relied upon to operate instantaneously and for long periods, even after months of storage.

The combination of miniaturization, ruggedness, and high performance makes this instrument ideally suited for advanced aircraft and missile applications where space and weight considerations are critical.

Write for Technical Bulletin BM-SLA8-1 to Minneapolis-Honeywell, Boston Division, Dept. 34, 1400 Soldiers Field Road, Boston 35, Mass., or call your local Military Products Group Office. Sales and Service offices in all principal cities of the world.



Internal view of LA-800, magnified 1.5 times



Subminiature Accelerometer LA-800, shown ¾ size

PERFORMANCE DATA

- **SIZE:** 1 inch in diameter by less than 1.5 inches (over terminals)
- **WEIGHT:** Approximately 3 ounces
- **DAMPING RATIO:** Any nominal ±20% from −65°F to +250°F
- **RANGE:** Up to 80 G
- **PICKOFF:** Variable Reluctance design provides infinite resolution and high signal-to-noise ratio
- **LOW THRESHOLD, EXCELLENT RESOLUTION:** 10^{-4}G
- **EXCELLENT LINEARITY:** ±0.5% to half-scale; ±2% to full-scale
- **LOW HYSTERESIS:** Less than 0.15% full scale
- **LINEAR ACCELERATION:** 10 G's or 3 times full-scale, whichever is greater.
- **LINEAR VIBRATION:** 15 G's to 2 kc for low G units; 30 G's to 2 kc for high G units

Consult Honeywell for your specific linear accelerometer requirements

- Small Size
- Simple Construction
- Reliable
- Self-Test Available

Honeywell

Military Products Group



Largest infrared dome ever manufactured in one piece. Measuring 12 inches in diameter, SERVOFRAX® *(arsenic trisulfide glass) dome is used on sensitive Navy search equipment.*

Looking 'way ahead in INFRARED

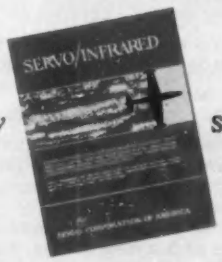
Servo Corporation of America has the distinction of being among the earliest pioneers in infrared technology. As far back as 1946, Servo recognized the tremendous potentialities of the versatile new science.

Years of consistent specialization... more than a million-and-a-half man-hours of experience have kept Servo a step ahead in infrared. This leadership has been earned by performance... by the ability to create and produce.

From a simple infrared lens to a complex infrared system... from design to production ...Servo makes available to all areas of industry and defense an impressive *capability in depth.*

Look to Servo for the solution

Send for new



SERVO/INFRARED CAPABILITIES BROCHURE
Contains full details on Servo's tremendous *capability in depth.*

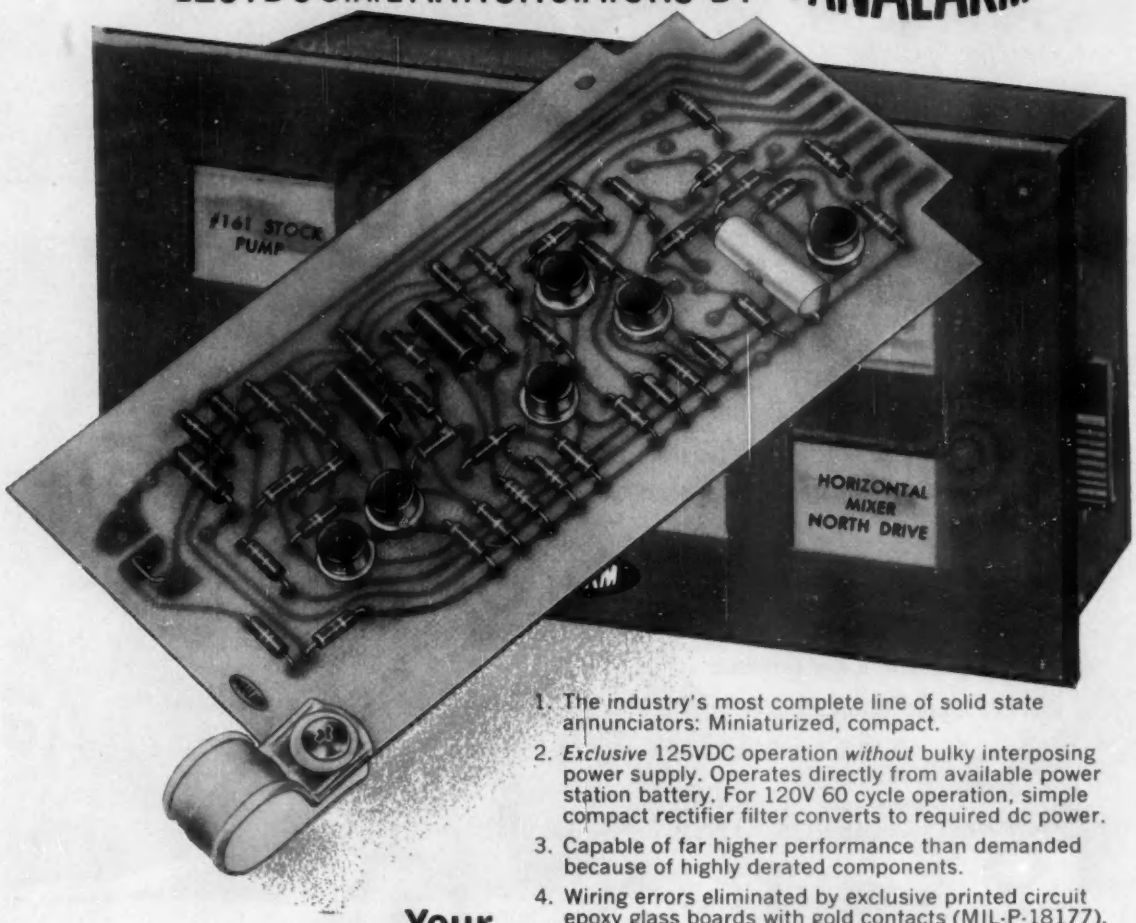
SERVO CORPORATION OF AMERICA

111 New South Road • Hicksville, L. I., N.Y. • WEIls 8-9700

INFRARED AIRBORNE SEARCH SYSTEMS • INFRARED DRONE SURVEILLANCE SYSTEMS • INFRARED FIRE DETECTION SYSTEMS • INFRARED TELESCOPES • INFRARED HIGH, LOW, AND MEDIUM ALTITUDE RECONNAISSANCE SYSTEMS • INFRARED MISSILE GUIDANCE SYSTEMS • INFRARED CALIBRATED RADIATION STANDARDS • INFRARED LENSES, WINDOWS, PRISMS, DOMES • INFRARED INDUSTRIAL RADIATION PYROMETERS • INFRARED RAILROAD HOT BOX DETECTORS

designed for decades of reliability

PANASTAT®
125VDC SOLID STATE ANNUNCIATORS BY PANALARM®



Your 6 Major Benefits

1. The industry's most complete line of solid state annunciators: Miniaturized, compact.
2. *Exclusive* 125VDC operation *without* bulky interposing power supply. Operates directly from available power station battery. For 120V 60 cycle operation, simple compact rectifier filter converts to required dc power.
3. Capable of far higher performance than demanded because of highly derated components.
4. Wiring errors eliminated by exclusive printed circuit epoxy glass boards with gold contacts (MIL-P-18177).
5. Readily obtainable . . . highly visible . . . standard 6S6 double contact bayonet 3-watt lamps.
6. Exclusive *safety* factor. Low energy control circuits feeding thru signal contact provide intrinsic safety. Thus the possibility of ignition in hazardous locations is minimized.

Panastat annunciators by Panalarm offer a new high in performance and a new low in maintenance. This is because there are no moving parts and because components are highly derated.

Your Panalarm Sales Engineer will be pleased to discuss Panastat Solid State Annunciators with you in complete detail. Call him today. Sales and engineering offices throughout the world.

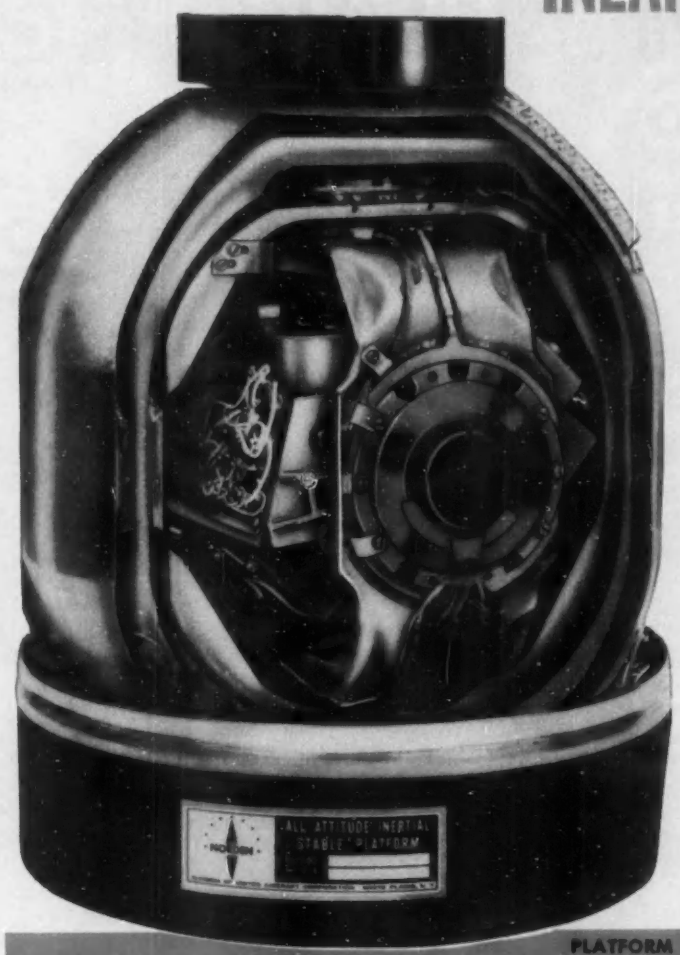
ISI PANELLIT

ANNUNCIATORS · CONTROL PANELS · DATA SYSTEMS

A division of ISI Incorporated

7401 North Hamlin Avenue, Skokie, Illinois · Phone ORchard 5-2500

INLAND d-c torque motors save critical weight in guidance systems



PLATFORM SHOWN ½ SIZE

Norden Miniature All-Attitude Inertial Platform uses four Inland torque motors, one for each gimbal axis.

Norden specifies these Inland d-c torque motors because of their compact pancake shape, low-power input and direct torquing. In addition to providing the obvious weight and space reduction, Inland's direct drive positioning eliminates gear train problems such as backlash.

Norden engineers say, "The linearity of the Inland torquers is excellent over a wide range so that precession rates may be accurately established. The torquer fixed field is carefully stabilized so that the torquer gradients will be constant over long periods of time."

Inland d-c pancake torque motors with high torque-to-inertia ratios and linearity of output provide all the advantages of direct gearless servo positioning in a complete line over the full range of 0.1 to 3,000 pound-feet.

COMPARE THESE TYPICAL INLAND TORQUER RATINGS

	T-1321-A	T-2136-A	T-2108-B
Peak torque, oz. in.	20.0	35.0	60.0
Volts at peak torque, stalled at 250°C	48.0	26.0	25.6
Amps at peak torque	1.21	1.6	1.24
Total friction, oz. in.	0.5	0.8	1.5
Rotor Inertia, oz. in sec²	.001	.007	.011
Weight, oz.	5.0	9.0	14.0
Dimensions (inches):—O.D.	1.937	2.81	2.81
I.D.	.625	1.00	1.00
Thickness	.50	.63	1.00

For complete catalog with engineering data, outline drawings and specifications on these and other Inland d-c pancake torquers, write Inland Motor Corporation of Virginia, Northampton, Massachusetts. Dept. 5-9.

INLAND MOTOR CORPORATION OF VIRGINIA
A SUBSIDIARY OF KOLLMORGEN CORPORATION
NORTHAMPTON, MASS.

CIRCLE 89 ON READER SERVICE CARD 89

POSITIVE SERVO SYSTEM STABILITY

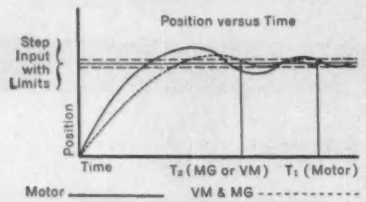
...now possible because Beckman® velocity-damped servomotors replace complicated rate-feedback systems!

Stability is one of the major problems facing today's servo systems designer. A damping technique of some type must be used when it is important that motors follow high gain input signals without oscillation or instability.

What's the best method of achieving stability? Helipot's answer is the Velocity-Damped Servomotor – with unique advantages over any other damping technique. These units introduce viscous friction, or damping, into the servo system by greatly simplified and extremely reliable electro-mechanical means.

Compare this to the damping generator. Velocity-damped servomotors can be used in nearly 80% of the applications where motor-generators are now being used. These new Helipot units eliminate amplifier feedback channels as well as the null voltage and phasing problems associated with motor-generator feedback loops. And velocity-damped units are more reliable, lighter in weight, smaller in size, and lower in cost.

Let's examine the facts.



Here's what happens. The figure above plots position against time, assuming a step input. It illustrates the difference in settling time between a standard servomotor and a Beckman Velocity-Damped Servomotor. Note that the velocity-damped unit, while not reaching its position as fast as the servomotor, does dampen out much sooner.

JUST HOW DOES VELOCITY-DAMPING WORK?

A magnetic damper section, consisting of a low inertia drag-cup integral with the motor shaft and two fixed permanent magnets, is attached to the servomotor in much the same manner as a generator. Currents are induced in the cup as it rotates around the magnets. The force exerted on the cup results in a retarding torque, or damping effect, on the motor shaft.

And this is adjustable damping. It's possible because polarity between the two magnets is variable, providing a means by which the total forces due to induced currents can be externally controlled. Even with the motor in operation, the amount of damp can easily be adjusted by setscrew and locknut.

WHERE CAN VELOCITY-DAMPED UNITS REPLACE MOTOR-GENERATORS?

The damping effect of velocity-damped units is directly proportional to speed in the same way that generators produce a feedback voltage proportional to speed. It follows that the two are theoretically interchangeable in position servo application.

And they are–up to 80% of the time. Their use is limited only where more damping is required than can be obtained from the two magnets. The factor here is one of physical size alone.

WHAT SPECIFIC ADVANTAGES DO VELOCITY-DAMPED UNITS HAVE?

You'll find that Beckman velocity-damped servomotors have 7 big plusses when compared to motor-generators. *Take a look.*

1. ELIMINATE NULL VOLTAGE AND PHASING PROBLEMS by replacing rate-feedback loops with magnetic damper section.

2. MORE RELIABLE because there is one less stator and its associated winding.

3. DAMPING ADJUSTMENT eliminates the need for trimming of circuits.

4. CONSUME LESS POWER because of the energy stored in the permanent magnets.

5. REDUCED TEMPERATURE SENSITIVITY due to direct application of drag torque to rotor.

6. SMALLER SIZE AND LIGHTER WEIGHT in sizes 11, 15, and 18.

7. AND...LOWER IN COST IN ALL SIZES!

Size	Model	Maximum Differential Range dyne cm. sec/rad.	
		Min.	Max.*
8	9008-1301-0	6	20
8	9008-1302-0	8	25
11	9011-1301-0	10	100

*Higher maximum damping is available at a sacrifice of differential range.

Beckman Velocity-Damped Servomotors are available in the above models, and also in sizes 15 and 18. They're precision-built by Helipot to give you a more effective method of overcoming stability problems.



The Beckman Size 8 and 11 Velocity-Damped Servomotors

WANT MORE INFORMATION? Detailed specs and additional product facts are included in the Beckman Size 8-11 Servomotor Catalog. It also contains all necessary transfer function equations for the calculation of your damping requirements. To get a copy, call your nearest Helipot Sales Engineering Rep or write direct.

Beckman INSTRUMENTS, INC.
HELIPOT DIVISION
Fullerton, Calif.
POTS : MOTORS : METERS

©1961 B-1-1, BH-62002-09

A NEW LINE OF

NIXIE®

INDICATOR TUBES



BEST FROM EVERY ANGLE

NIXIE Tubes, the established readout standard for the electronics industry, now have another major feature . . . . 160° viewing angle. These tubes which are noted for their constant brightness, outstanding life (100 times that of any other readout), low cost, small size, light weight and excellent readability, have the widest viewing angle ever achieved in a direct decimal readout device. NIXIE Indicator Tubes . . . . . Best From Every Angle.

Write for complete data on the new NIXIE Indicator Tube line.

ANOTHER ELECTRONIC CONTRIBUTION BY

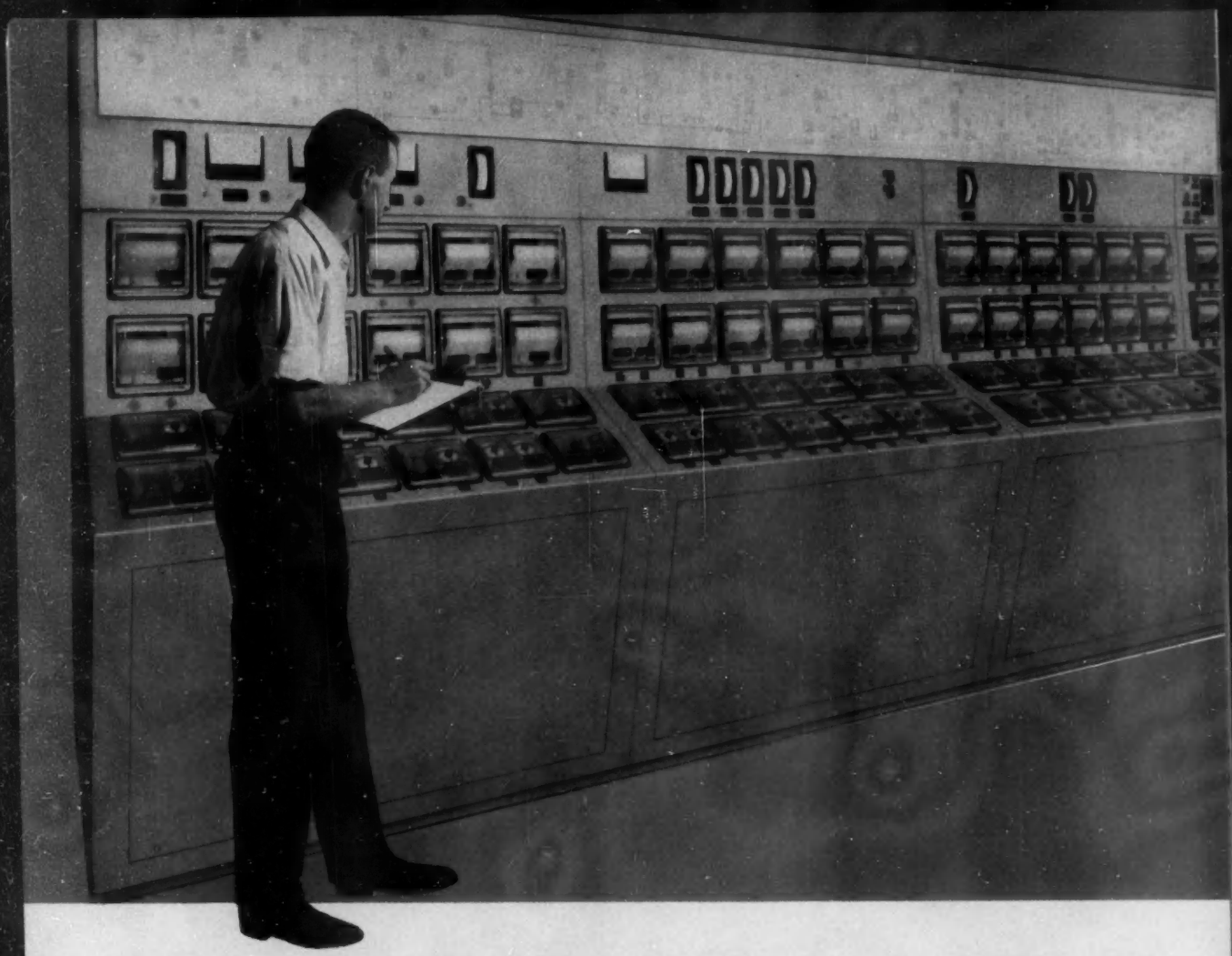
Burroughs Corporation

ELECTRONIC COMPONENTS DIVISION

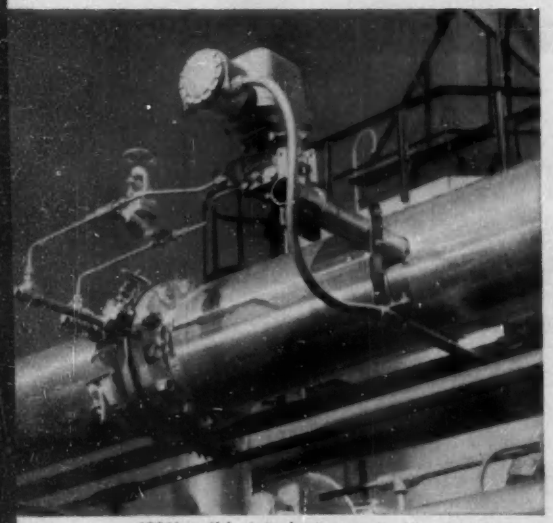
PLAINFIELD, NEW JERSEY

Formerly Electronic Tube Division

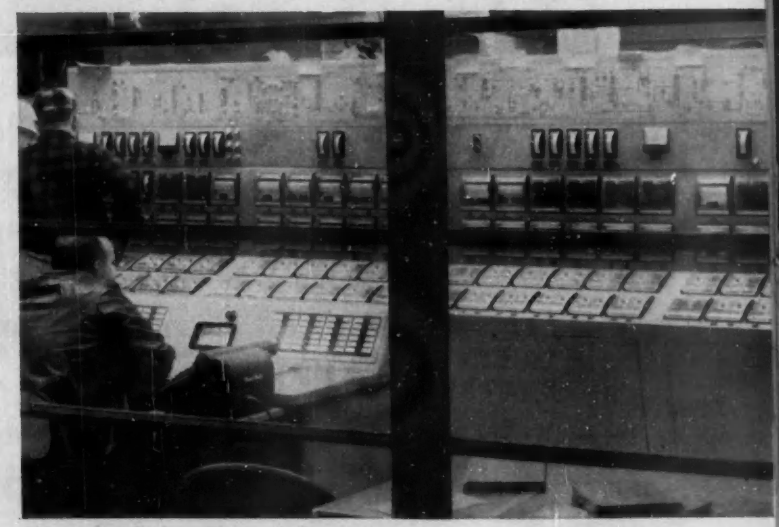
CIRCLE 91 ON READER SERVICE CARD



Foxboro Electronic Consotrols* shrink

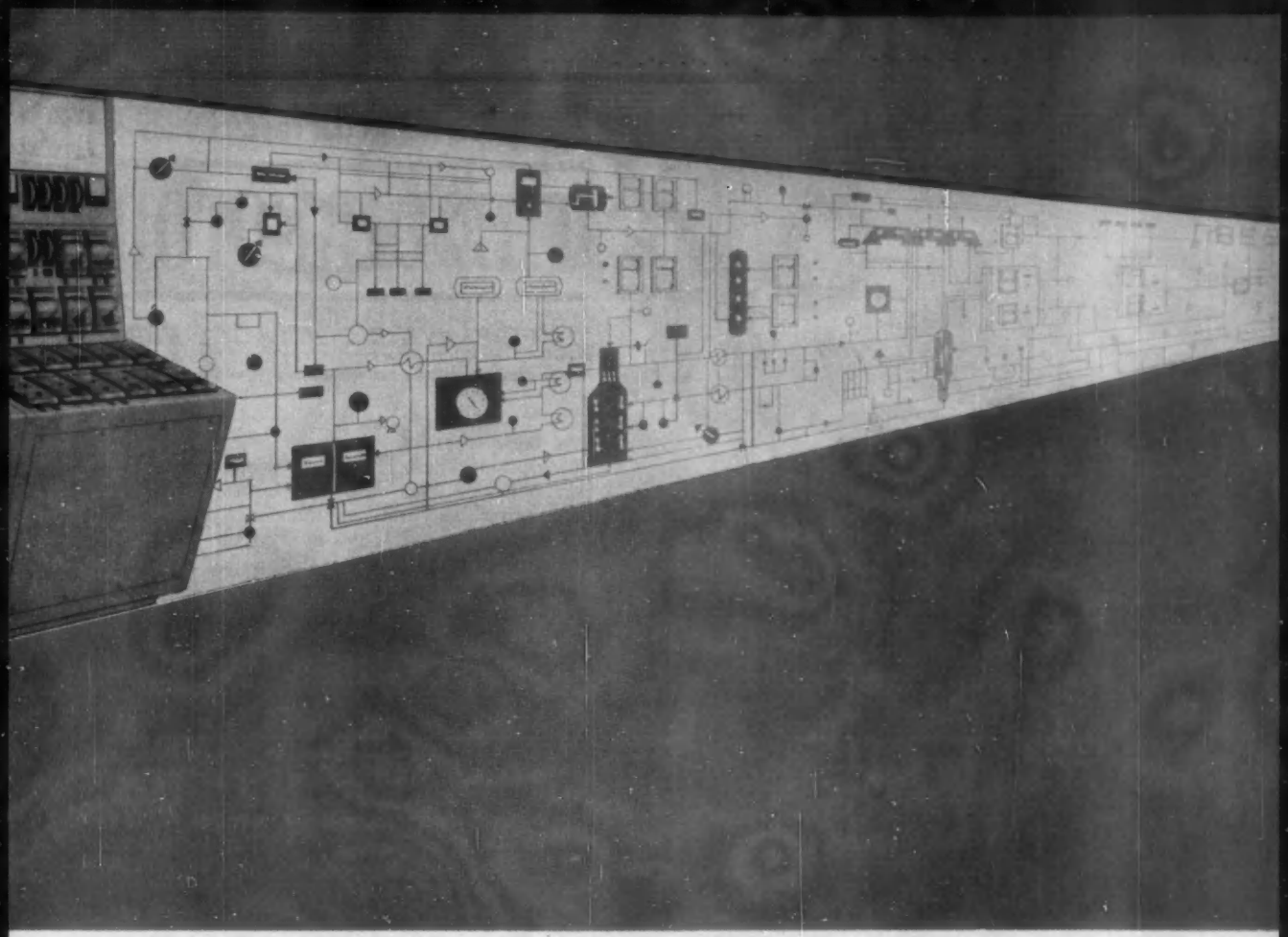


100% solid state instruments, like this Foxboro Type 613 d/p Cell* Flow Transmitter, were used in all control loops to assure instant transmission over long distances. **Reg. U. S. Pat. Off.*



Fifteen-foot Foxboro Electronic Console permits fast scanning of instruments — gives dependable control of Alkar† unit, styrene plant, and steam plant for Cosden Petroleum.

†Trade mark Universal Oil Products Co. — Process Licensor
Badger Manufacturing Co. — Contracting Engineers



panel length 66% for Cosden Petroleum

Panel planned for 45 feet, then reduced to 15 feet with Foxboro "small case" Electronic Consotrols



Space saving has taken on a new meaning at Cosden Petroleum Corp. At Cosden's Big Spring, Texas refinery, a UOP Alkar† unit, a styrene plant, and a steam plant are all electronically controlled by one 15-foot Foxboro Modular Console.

When Cosden Petroleum specified Foxboro "small case" Electronic Consotrols and modular consoles, 30 feet of panel space were eliminated for a considerable saving in building construction costs alone.

What's more, Foxboro packed 61 Electronic Consotrol Controllers, plus 100 indicating and recording points into the 15-foot panel — and there's still room to spare for tomorrow's instrumentation needs! Spare panel cut-outs for 35 more controllers and 9 more recorders are pre-wired and ready for service. All Cosden needs to do is hook up the transmitter leads at the bottom of the cabinet and slip the recorder or controller into the panel.

Maintenance men also like the easy way they can transfer instruments on the modular console. Instruments slide in and out of their housings as easily as drawers. A simple plug-in connection puts the instruments into action.

You too, can save space, save time, save money — with Foxboro Electronic Consotrols.

Write for Bulletin 9-12. The Foxboro Company, 859 Neponset Avenue, Foxboro, Massachusetts.

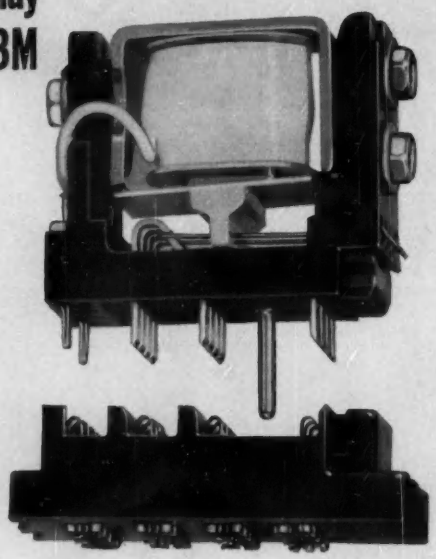
Reg. U. S. Pat. Off.

FOXBORO

REG. U.S. PAT. OFF.

CIRCLE 93 ON READER SERVICE CARD

New Relay from RBM



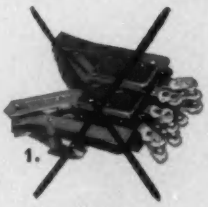
Compact, Rugged, Proven Reliable

THE DIRECTOR

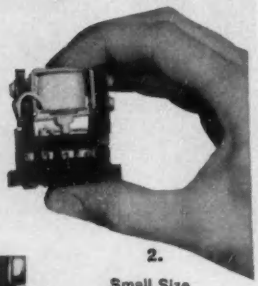
TYPE 81 WIRE CONTACT RELAY

Specifically designed to direct or set-up circuits in the logic or arithmetic section of computer and business machines. The RBM "Director" has also demonstrated itself ready to perform in similar applications where the basic function of the contacts of one or more relays sets up a circuit, but is not required to make or break that particular circuit. Typical uses would be controls for automation, railway signaling, traffic controls, chemical process controls, annunciators and many others.

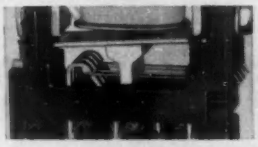
Designed for high speed and long life (200 million operations).



1. No soldering



2. Small Size

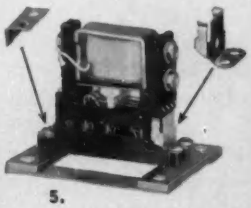


3. Wire contacts

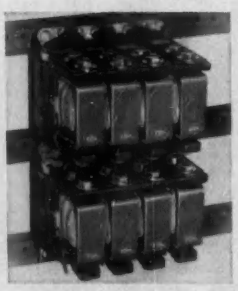


"A"→

4. Program connectors



5. Rugged snap-in plug assembly



6. Rack mounting

1. Plug-in terminal and mating terminal block eliminates messy soldering and maintenance problems of old fashioned telephone type relays.

2. Symetrical shape and rugged design provides for minimum mounting space and maximum protection to moving parts when handling.

3. Armature contacts consist of two silver alloy wires per pole providing highly reliable redundant contact surfaces.

4. With plug-in connectors "A", relay contacts can be "programmed" to suit specific circuit requirements.

5. Special hardware available allowing for mating terminal block assembly and easy mounting on chassis or rack.

6. The Type 81 relay can be easily assembled in groups, simplifying wiring and ease of programming. Requires minimum rack or chassis space.

TYPE 81 SPECIFICATIONS

Contact Form	4 PDT
Contact Rating	3 amp. (carry only)*
Contact Material (Std.)	Eutectic Alloy—Silver-Copper
Operating time (Nom.)	5.5 milliseconds max. inc. bounce
Life	200 million operations
Coil Form	Single or Double Winding (Pic & Hold)
Coil Voltage	20 volts D.C. thru 115 volts D.C.
Coil Power	4 watts max.
Breakdown Voltage	1250 volts RMS 60 cycle to frame
Ambient Temperature	50° C
Weight	Approximately 1¼ oz.
Overall dim. (Approx.)	Including plug—2⅛" x ⅝" x 2"

**Consult Factory for Ratings for Making and Breaking Loads.*

Consult Your Local RBM Product Application Engineer or Write for Bulletin 2000

CONTROLLING RBM QUALITY THE FUTURE

RBM Controls Division

LOGANSPORT, INDIANA

Factories Located at North Manchester and Logansport, Indiana



MICROCIRCUITRY AVAILABLE IN QUANTITY

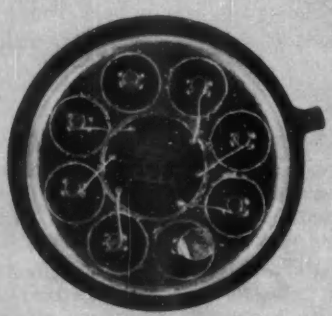
THREE NEW FAIRCHILD MICROLOGIC COMPUTER ELEMENTS Available for immediate volume delivery are the Flip-flop, the Gate, and the Half-shift Register. These high-speed, low-power devices operate at bit rates in excess of 1 mc. For the first time complete arithmetic and control sections can be produced with SILICON PLANAR, SINGLE CHIP logic building blocks.

DESIGN AND ASSEMBLY COST REDUCTIONS— UP TO 90% Fairchild Micrologic elements can reduce system design and assembly costs up to 90%, space requirements up to 95%, and power needs up to 75%, thus making many new computer applications practical and economically feasible. They can be used over the full military temperature range (−55° C. to +125° C.).

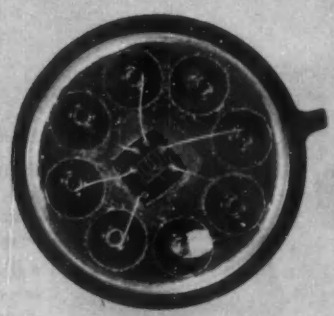
RELIABILITY—500,000 HOURS AT 125°C The equivalent of 3,000,000 component operating hours without a single failure. A new order of stability and reliability is made possible by the Fairchild Planar process with total protection of the passivated oxide surface.

SILICON PLANAR SINGLE CHIP CIRCUITS

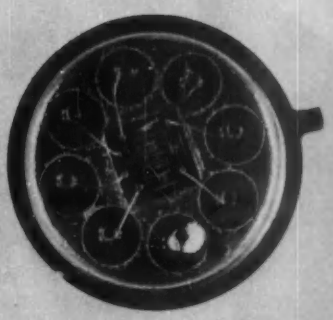
UNRETOUCHED PHOTOGRAPHS MAGNIFIED 5 TIMES



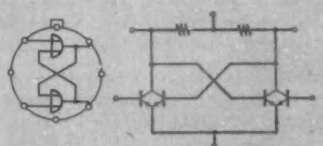
"F" FLIP-FLOP
TO-5 size header

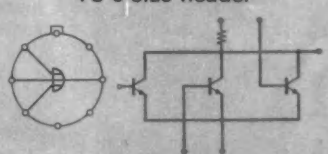


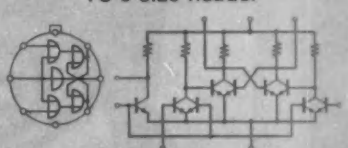
"G" GATE
TO-5 size header



"S" HALF-SHIFT REGISTER
TO-5 size header







NOR DIAGRAMS AND CIRCUITS FOR EQUIVALENT FUNCTIONS

For complete data, specifications and pricing information contact your Fairchild Field Sales Office. Or write direct. Three additional elements (the Half-adder, Buffer and Counter Adapter) will be available soon to complete the Fairchild Micrologic family.

μL and μLogic are trademarks of Fairchild Semiconductor, a Division of Fairchild Camera and Instrument Corporation

FAIRCHILD
SEMICONDUCTOR

545 WHISMAN ROAD, MOUNTAIN VIEW, CALIF. - YORKSHIRE 8-8161 - TWX: MN VW CAL 853
A DIVISION OF FAIRCHILD CAMERA AND INSTRUMENT CORPORATION

HOW FAR . . . AND HOW FAST . . .

can you use computer control *profitably?*



BAILEY 700 SYSTEMS CAN HELP YOU DETERMINE THIS—ONE STEP AT A TIME

Can computer control be used—profitably—in your process operations?

Where and how?

The answer often lies in intermediate stages of improvement in sensing, measuring, controlling, computing.

Bailey engineers can help you determine and prove — one step at a time — how far analog or digital systems can be profitably applied in your operations. Bailey is equipped, by broad experience, to provide single-source responsibility from sensing and measuring instrumentation to complete automation. *Bailey 700 Systems* are installed, in operation, or on order, at locations from coast to coast and throughout the world.

Find out what this Bailey background can offer. Contact your Bailey District Office.

SIX STEPS TO FULL AUTOMATION

Centralize and simplify information display—use analog and digital techniques to clarify information, aid operator understanding, improve reliability of interpretation, and save space.

Extend use of interlocks and limiting circuitry—use digital solid-state components to extend supervisory controls, thereby minimizing effects of human error.

Increase use of automatic sub-loops—simplify and standardize the starting, controlling, and stopping of major plant components and sub-systems.

Extend on-line controls—integrate sub-loops, interlocks, and limiting controls with conventional controls to secure automatic operation over full range, once unit is on the line.

Provide performance monitoring—add computing facilities to provide significant up-to-date calculations for operation improvement and maintenance scheduling.

Integrate all system elements—add start-stop control to provide full automation, the ultimate goal.

G 158-1

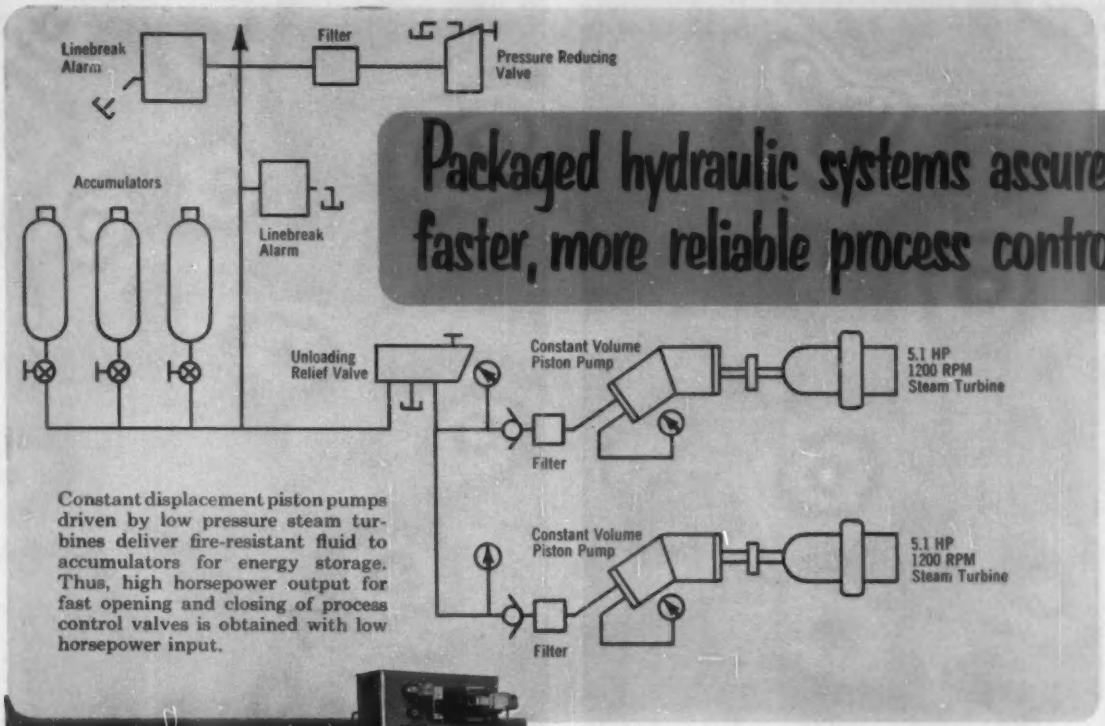
INSTRUMENTS, CONTROLS, AND SYSTEMS

BAILEY METER COMPANY

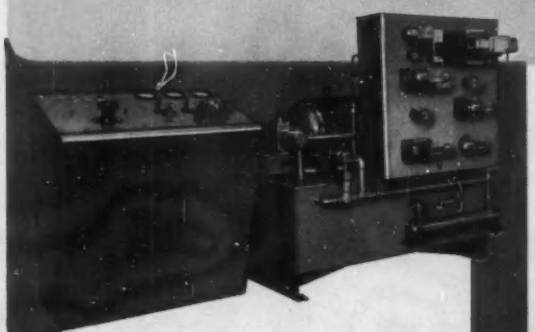
1079 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

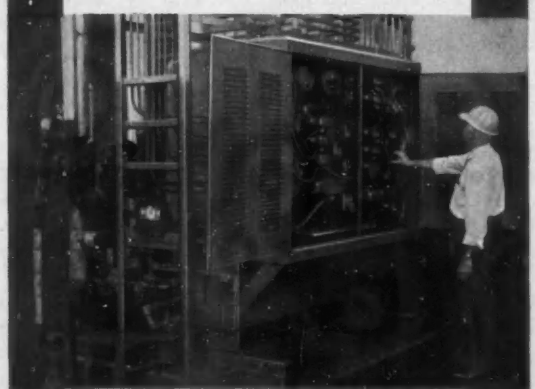
Packaged hydraulic systems assure faster, more reliable process control



Constant displacement piston pumps driven by low pressure steam turbines deliver fire-resistant fluid to accumulators for energy storage. Thus, high horsepower output for fast opening and closing of process control valves is obtained with low horsepower input.



Control console and power unit form electro-hydraulic system for controlling automatic heat treatment cycle. Physical layout provides optimum circuit efficiency, ease of servicing, and good appearance.



This power package includes all hydraulic pumps and valves for complete control of automatic cyclic operation of process in a butadiene plant.

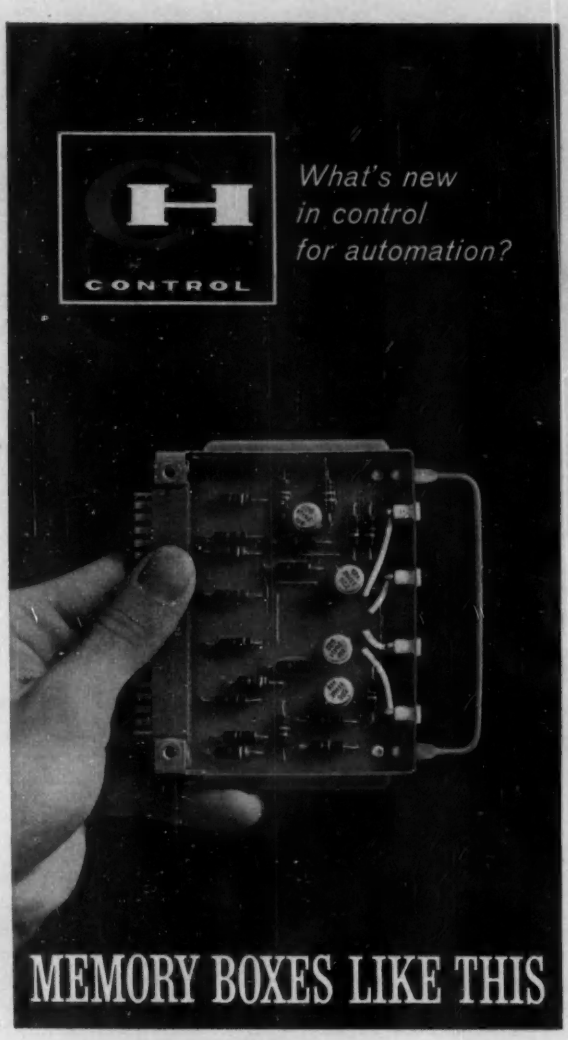
Fast and precisely controlled motions, having the high reliability demanded by modern processing, are inherent characteristics of hydraulics. In addition, these advantages are obtained at low cost, for you can cover your full range of operations—from valve control to power transmission—with standard Vickers components. Your engineers enjoy unlimited design flexibility through a choice of electric, electronic, pneumatic and manual signals to control the hydraulic pumps, motors, cylinders, and variable speed drives.

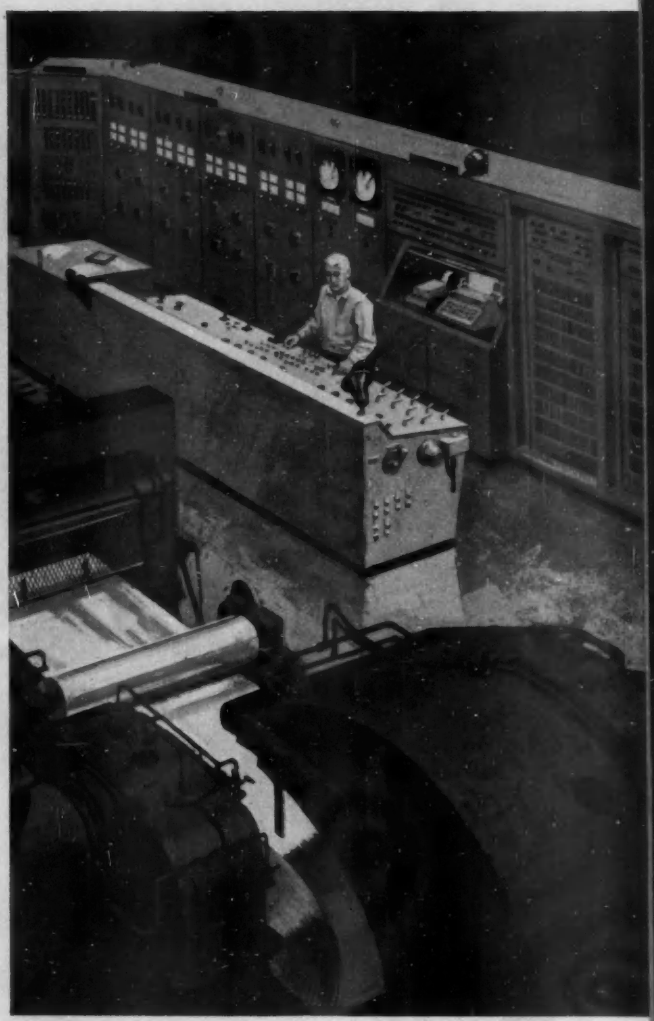
Vickers complete packaged systems are ready to go into service upon arrival in your plant, since they are thoroughly pretested before shipment. They are properly designed and built to give maximum service life with little downtime, thus helping to keep your plant on stream.

Get more information on the job being done by Vickers packaged hydraulic systems in chemical, petrochemical, petroleum refining, and other processing industries by writing today for Bulletin I5802, "Packaged Hydraulic Systems for Process Control."

VICKERS INCORPORATED
DIVISION SPERRY RAND CORPORATION
ADMINISTRATIVE and ENGINEERING CENTER
Department 1606 • Detroit 32, Michigan

9138





SAVE MATERIALS . . . *to help a tinplate producer control quality,* Cutler-Hammer designed a computer that records quality in coils 3 miles long as the strip zips by at 1600 FPM. Automatically typed report shows defects and their exact location. Next automation step: process the data and close the loop by feeding the system instructions to provide automatic correction of process defects.

READ, RECORD, REMEMBER

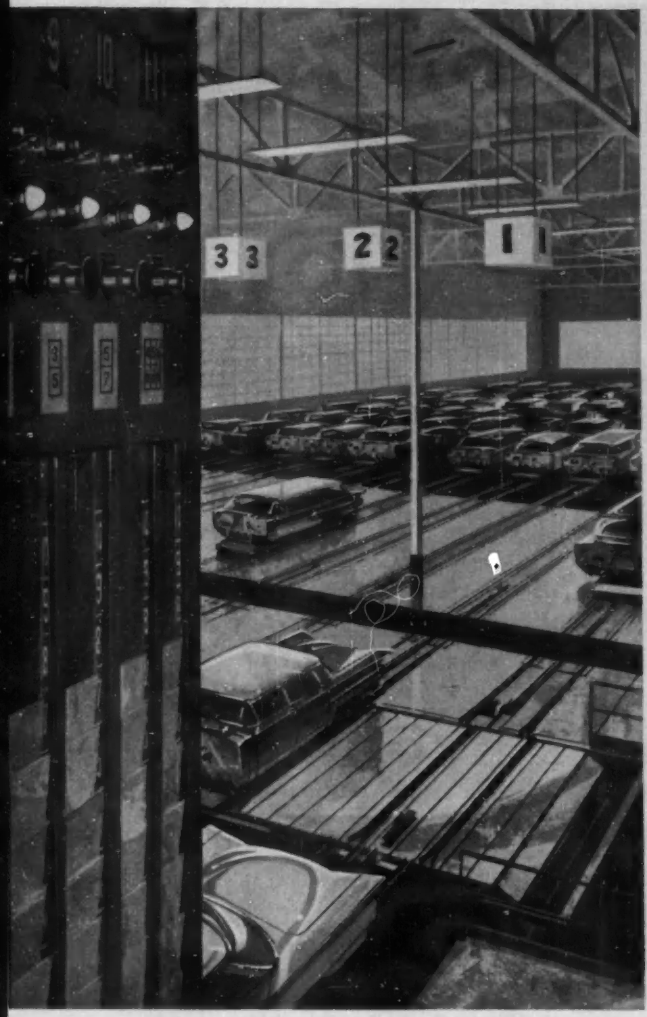
Memory boxes like this—digital modules in various combinations—are the key to *data accumulation*, basic to automation. Data accumulation provides *facts* that enable an operator to control a process better. It provides the *complete knowledge* of what is happening in a process that is an essential preliminary to complete automation.

Three examples of data accumulation that have paid off are shown above. Applications are as broad as your problems and engineering imagination. Typical applications are designed to improve production and inventory control, to provide better sales forecasting, more intelligent production scheduling and cost control.

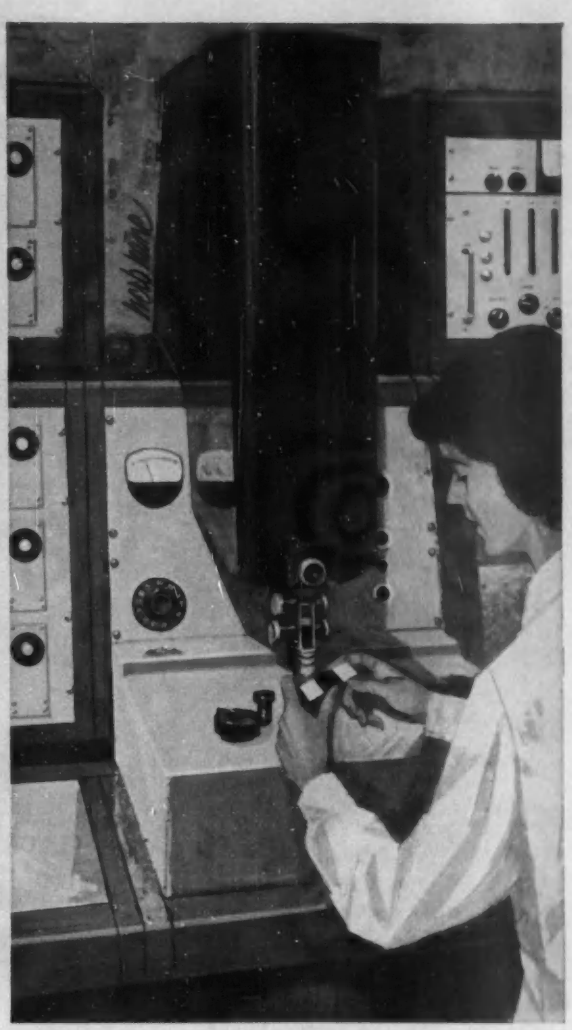
Automation systems designed by Cutler-Hammer run the gamut from material-handling systems that automatically regulate flow of car bodies from warehouse to assembly, to automatic blast furnace charging.

COMMON DENOMINATOR OF SUCCESSFUL AUTOMATION

You, and your automation planning team, can establish the needs for automation in your company far better than anyone else. But when objectives are determined, an automation control specialist can help you increase efficiency and cut costs . . . especially when he is *called in early*. He will help you select data processing equipment with the exact degree of sophistication for your needs; make sure that control and mechanical drive are compatible.



SAVE TIME . . . *to prevent production delays*, a buffer storage area between car body plant and assembly was designed by Cutler-Hammer engineers. One operator assigns body styles to assembly in sequence to maximize production, utilizing simplified data processing which "remembers" each car body location. This Cutler-Hammer idea saved the manufacturer many thousands of dollars.



SAVE LIVES . . . to detect the presence of abnormal and cancer cells faster, the Cytoanalyzer developed by Cutler-Hammer's AIL Division automatically classifies and counts abnormal cells according to the size and optical density of their nuclei. This instrument is capable of greatly increasing the case load of cancer screening staffs, and holds the promise of saving lives through early detection of cancer.

Employment opportunities are available for qualified engineers.

WHAT'S YOUR AUTOMATION OBJECTIVE?

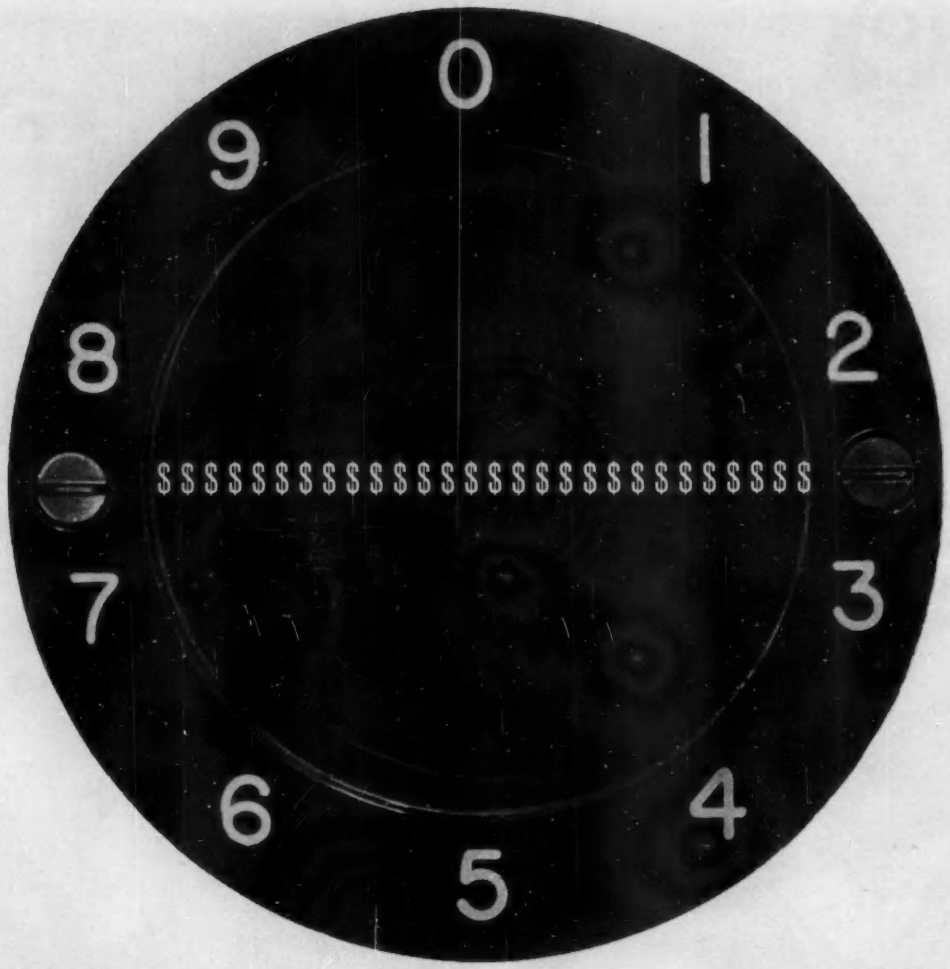
Chances are Cutler-Hammer engineers can utilize their automation experience and adapt existing techniques to help solve your problem. Or, they'll use their ingenuity to develop a completely new concept. Either way, you have everything to gain from their experience. Why don't you call in your Cutler-Hammer man this week?

WHAT'S NEW? ASK...

CUTLER-HAMMER

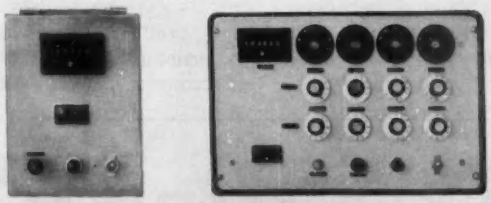
CONTROL

Cutler-Hammer Inc., Milwaukee, Wisconsin • Division: Airborne Instruments Laboratory • Subsidiary: Cutler-Hammer International, C. A. • Associates: Cutler-Hammer Canada, Ltd.; Cutler-Hammer Mexicana, S. A.

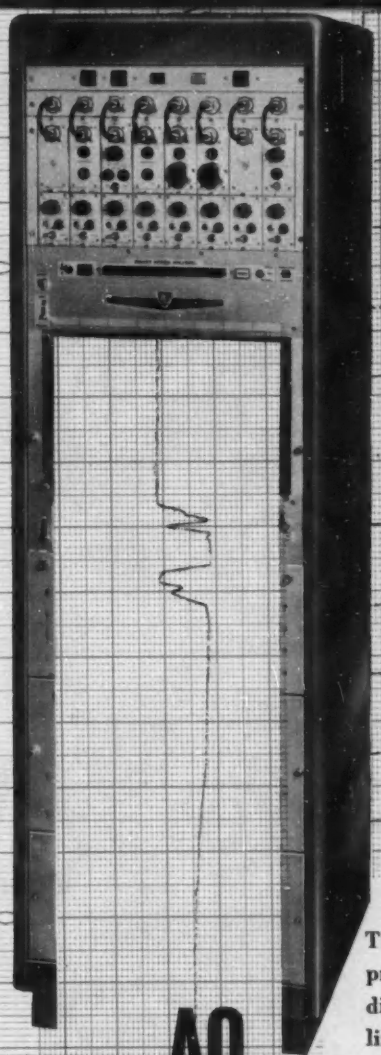


What price Automation? Veeder-Root's electronic answer will surprise you! Now you can buy automatic electronic counting and controlling functions on a "tailored to fit" basis. Just what you need to step up efficiency and cut costs. No more!! No less!! Start with what you want to count... next determine the fastest counting speed you need... then consider how you could automate your equipment by triggering one or more of its operations electrically.

With these basic facts, your Veeder-Root sales engineer can tell you which electronic counters will meet your automation requirements most economically. These compact units can count up to 300,000 times per minute. They can sense objects the size of a pinhead. Control types are easily preset to start, stop and regulate your equipment... and accurately coordinate its production. Find out how little it costs to build automation into your production setup. Write to Electronic Controls Division, Veeder-Root Inc., Danvers, Mass. **count on... Veeder-Root**



The Veeder-Root electronic counter line ranges from the 1697 Count-Pak for counting to 2500 cpm at a unit cost of approximately $100 . . . to the highly versatile 1804 series for counting up to 300,000 cpm and controlling any number of operations.



AO Trace-master provides twice the definition

The unique direct-carbon-transfer writing method produces a trace from 2 to 3 times finer than any other direct-writing technique. This allows twice as many lines per millimeter . . . twice the definition! Resolution is unsurpassed . . . each line is uniform in width and contrast, revealing the most minute variations in the phenomena measured with utmost fidelity. This writing technique combined with the advanced pen-motor design produces a wider frequency response at larger amplitudes. Continuous recording of data can be displayed simultaneously on 8 channels . . . up to 8 independent event markers can be added. Ten chart speeds — 0.1 to 500 mm/sec — provide a 5000:1 chart speed ratio.

The AO Tracemaster has become the new standard of performance for these and many other reasons . . . write now for the full story!

See the AO TRACE MASTER . . . plus other advanced direct writing recorder instrumentation at I.S.A. Booth 323

American Optical COMPANY

INSTRUMENT DIVISION, BUFFALO 15, NEW YORK

CIRCLE 101 ON READER SERVICE CARD

EAST VS. WEST

DIAGRAMS VS. EQUATIONS

THE COMPUTER'S ANSWER TO A LONG-STANDING COMPUTER ISSUE.

For a decade East Coast and West Coast computer designers have been using different methods of representing computer logic—the Easterners with diagrams, the Westerners with equations.

$$LBSMI = (LXA1)(LXA2*)(LFCA*) + (LXA1*)(LXA2)(LFCA*) + (LXA1*)(LXA2*)(LFCA) + (LXA1)(LXA2)(LFCA)$$

$$LFCAJ = (LXA1)(LXA2)$$

$$LFCAK = (LXA1*)(LXA2*)$$

In the example illustrated here, the diagram and the equation tell us exactly the same thing. Either represents a serial full adder where the sequence of pulses at the output, LBSM, will represent a serial binary number that is the sum of two serial binary input numbers occurring at LXA1 and LXA2. (The asterisks indicate binary complements; for example, whenever LXA1 is energized LXA1* is not, and vice versa. LFCA is a carry flip-flop.)

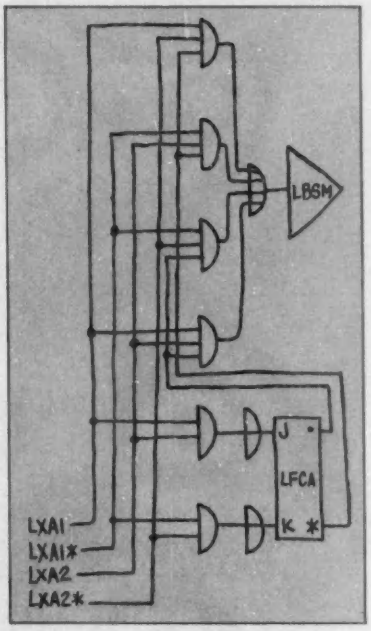
There are persuasive arguments on both sides. Eastern proponents of diagrams point out that the logical interconnections can be seen at a glance and followed through any number of stages by eye. The logical structure of an entire system can be understood from a diagram more directly and intuitively, they maintain, than from a set of equations.

The Western argument for equations goes like this. It's not true that diagrams communicate better to the viewer's intuition, except at first exposure. The human mind is highly adaptive. After working analytically with the equations for a while, the mind begins to operate intuitively in that symbology. Then the intrinsic superiority of equations over diagrams begins to make itself evident. One advantage, say the Westerners, is that equations can represent the same information more compactly and efficiently, as our illustration shows. Another is that equations lend themselves better to computer manipulation of logical design information.

As evidence of the latter advantage Westerners point to a recent achievement of some Litton Systems people: a completely mechanized procedure for translating logical designs into wiring lists, including operational simulation of the design to verify its accuracy. A procedure enormously facilitated by the computerizability of logical equations. It's easy to picture the benefits in cost, delivery schedules, reliability, price. Using only a partial development of this method Litton Systems recently brought a major computer system from concept to operation in less than a year.

Now under consideration at Litton: a machine that will accept as inputs a supply of standard computer components and a set of coded specifications defining the logical functions desired, and will crank out completely fabricated systems.

Maybe you think we've loaded the argument in favor of equations. You're right. But we're ready to listen to arguments on either side. Drop us a card. Or better still, drop in in person. You'll like the



imagination-stretching atmosphere generated by Litton management's appreciation of the rewards of creative controversy. And we have a few excellent opportunities for computer design people. Ask for S. L. Hirsch at Litton Systems, Inc., Data Systems Division, 6700 Eton Ave., Canoga Park, California.

An equal opportunity employer

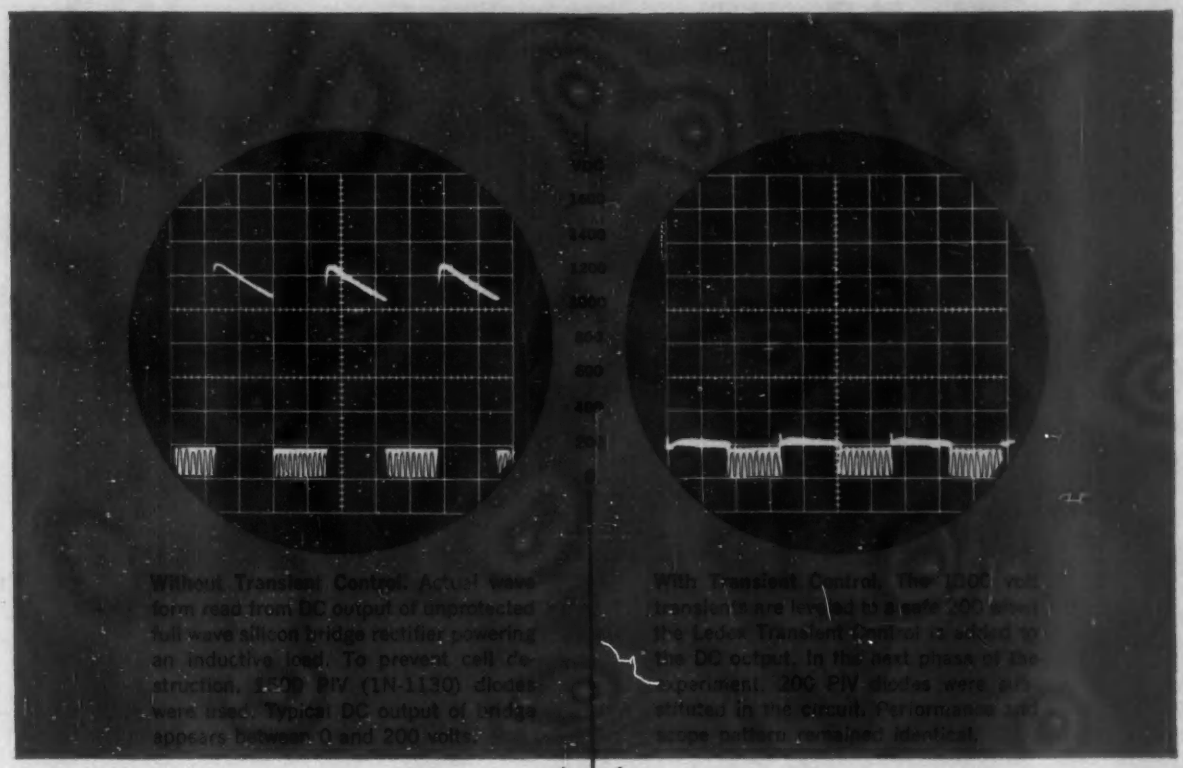




LITTON SYSTEMS, INC.

A DIVISION OF LITTON INDUSTRIES

DATA HANDLING & DISPLAY SYSTEMS · GUIDANCE & CONTROL SYSTEMS · COMPUTER SYSTEMS · SPACE SCIENCE · BIOELECTRONICS · ADVANCED COMMUNICATIONS TECHNOLOGY



Without Transient Control. Actual waveform read from DC output of unprotected full wave silicon bridge rectifier powering an inductive load. To prevent cell destruction, 1,200 PIV (1N-1130) diodes were used. Typical DC output of bridge appears between 0 and 200 volts.

With Transient Control. The 1200 volt transients are limited to a safe 200 when the Ledex Transient Control is added to the DC output. In the next phase of the experiment, 200 PIV diodes were substituted in the circuit. Performance and scope pattern remained identical.

New low-cost Transient Control* makes silicon rectifiers reliable by clipping voltage spikes

The new Ledex Transient Control guarantees positive dependability of 200 PIV silicon rectifiers. It's a non-polarized device that automatically clips voltage spikes by providing a low resistance shunt for all potentials above 200 volts—on the AC or DC side. It draws no current in normal operation.

As shown in the actual scope shots above, the control will repeatedly clip transients or reverse voltages to a safe level of 200. To the design engineer, it is a guarantee that the maximum voltage will go no higher than 200. Compact, light, and economical, the new development puts low-cost 200 PIV diodes in a reliability class of their own.

While the device is mainly intended for protection of 115 VAC silicon rectifier circuits, it can also be designed to clip spikes and protect other semi-conductor circuits at lower or higher control voltages.



☐ **NEW LEDEX TRANSIENT CONTROL** is small (¾" dia. by 1⅜" long), lightweight (⅔ oz.) low cost ($1.60 to $2.05 in small quantities). Part No. A-46800-001 has 200 volt control and 2" leads.



☐ **NEW LEDEX SILICON BRIDGE RECTIFIER** is protected by a built-in Ledex Transient Control. Voltage spikes are automatically clipped at 200. The rectifier is sealed in epoxy resin and meets the general requirements of MIL-E-5400 on insulation, terminals, vibration, shock, sand and dust, fungus and salt atmosphere. Operating temperature is −65°C to +120°C. Part No. A-46501-001 is rated as follows: 115 volt AC input, 100 volt DC output, maximum surge 50 amp for 8 msec. $6.80 to $8.15 in small quantities.

☐ **VALUE ANALYSIS RECTIFIER TRANSIENT CONTROL KIT** consists of Transient Control, Silicon Rectifier with built-in Control and outline for evaluation tests to compare costs and reliability with your present circuits. Part No. A-47607-001. $11.00 per kit.

Other Ledex products are ready to go to work as compact solutions to your actuating, stepping or circuit switching applications.

FOR LITERATURE, clip this ad, check boxes above, attach to your letterhead and mail to Ledex Inc., Dayton 2, Ohio; Marsland Engineering, Ltd., Kitchener, Ont.; NSF Ltd., 31 Alfred Place, London, Eng.; AEMGP, 115 Ave. Clement, Boulogne, France.

* PAT. PENDING

LEDEX

CIRCLE 103 ON READER SERVICE CARD 103

the new SL-2... a standard limit switch with unlimited operating flexibility



Tailor limit switch performance to your specific job with NAMCO'S *standard* SL-2. This "machine life" limit switch features a standard cam blank which can be cut into a wide variety of configurations to meet any application. These interchangeable cams provide positive control of contact sequence; let you match switch operation to your specific job. Ruggedly built, oil-tight and moisture-proof, the SL-2 provides dependable, accurate performance that meets your most precise requirements.

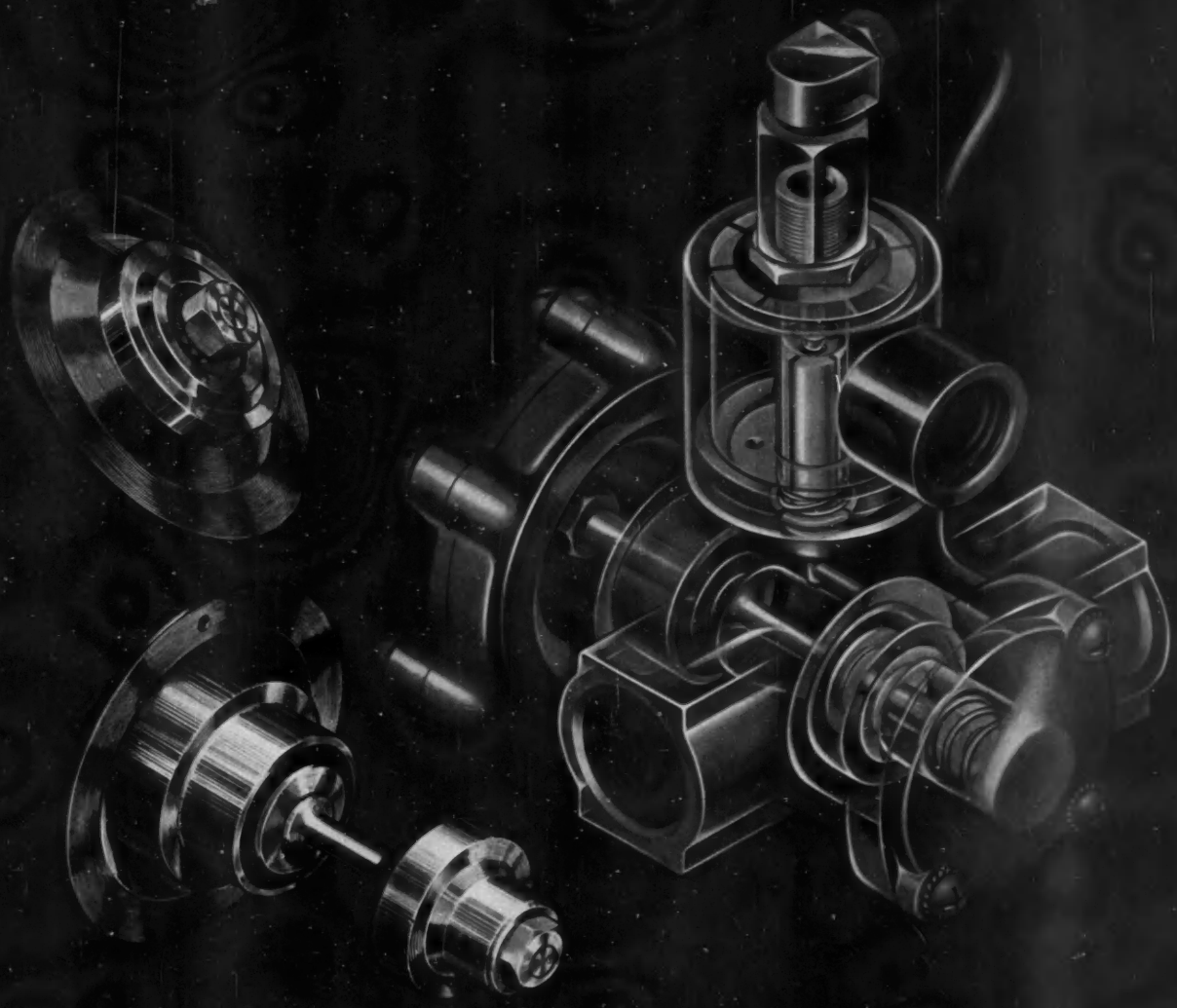
Now available for low-current, high-shock, excessive-vibration applications...the SLS-2... with full-wiping, self-cleaning sliding contacts that insure "everytime" operation under conditions that spell machine downtime for other limit switches.

Get all the details on how the NAMCO SL-2 line eliminates limit switching problems for good. Write for Bulletin EC-SL260, or contact one of our representatives. You'll find them in all principal cities.

National Acme

THE NATIONAL ACME COMPANY
165 E. 131st STREET
CLEVELAND 8, OHIO

Sales Offices: Newark 2, N. J., Chicago 6, Ill., Detroit 27, Mich.



SKINNER *2-way and 3-way Solenoid Valves*

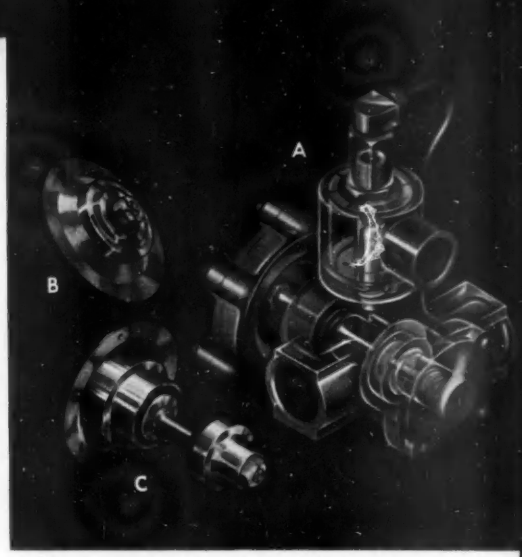
for high flow, heavy-duty industrial use

Skinner combines unique diaphragm assembly and V5 solenoid operator in new L Series valves

Skinner has now combined its famous V5 solenoid operator with a unique diaphragm assembly in a new line of two-way and three-way valves—the versatile L Series.

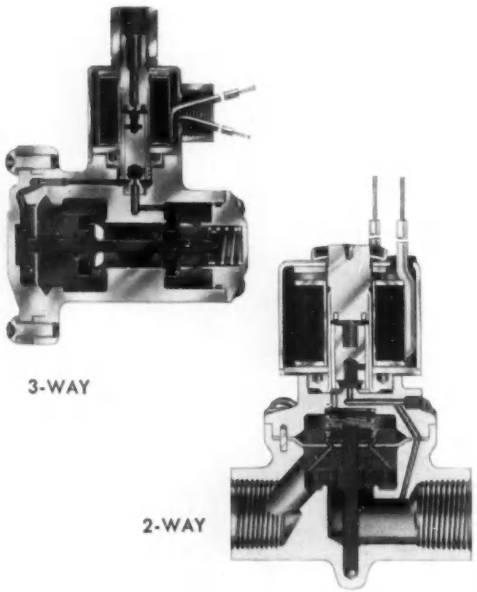
Unusually long life is assured by this new diaphragm assembly. The 3-way diaphragm consists of two tough laminates of nylon fabric coated with a Buna-N rubber separated by a thin Teflon disk. The assembly is virtually 100% supported in the open and closed positions with only a very small area exposed to pressure differential during operation. Life tests show that this type of diaphragm far out-performs all others tested.

The two-way diaphragm and spindle assembly supports a seal retainer and soft, synthetic seal which provides bubbletight sealing of the main orifice. This seal fits on a shoulder which extends beyond the seat and helps to cushion the closing motion—thus minimizing water-hammer.



A—Transparent view of normally closed 3-way solenoid valve
B—Front view of diaphragm assembly
C—Spindle seal retainer and diaphragm assembly

Low cost 2-way and 3-way valves to meet your high flow industrial requirements



Cutaway views of 2-way and 3-way valves showing how the unique diaphragm assembly and solenoid operator are combined in these new valves.

Skinner L Series solenoid valves feature forged naval brass bodies, stainless steel and brass internal parts. They are available normally closed, normally open and directional control in standard and explosion-proof construction.

In addition to the many exclusive features, these Skinner valves are low in price, and with one model—a 2-way normally closed valve—available at especially low budget cost.

All 3-way and 2-way normally open valves are supplied with a piped exhaust return. For catalogs and complete information, contact a Skinner Distributor listed in the Yellow Pages or write us at the address below.

SKINNER L SERIES SPECIFICATIONS

	TWO-WAY	THREE-WAY
Pipe Sizes, NPTF	⅜"*, ½", ¾", 1"	⅛", ½", ¾"
Orifice Sizes	½", ¾", 1"	⅜", ½", ¾"
Operating Pressure Differential — Minimum	5 PSI	5 PSI (⅜" 10 PSI)
Operating Pressure Differential — Maximum	150 PSI	150 PSI
Position	Normally closed, Normally open	Normally closed, Normally open, Directional control
Leakage	Bubbletight	Bubbletight
Temperature Range (Ambient and Media)	Minus 40°F to plus 180°F	Minus 40°F to plus 180°F

*has ½" orifice

When you specify solenoid valves, specify Skinner.

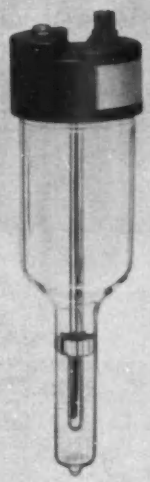
Skinner solenoid valves are distributed nationally.

SKINNER ELECTRIC VALVES

THE CREST OF QUALITY

SKINNER ELECTRIC VALVE DIVISION
SKINNER PRECISION INDUSTRIES, INC. • NEW BRITAIN, CONNECTICUT, U.S.A.

PRINTED IN U. S. A.



...with new rugged 7" reference and 3¾" glass electrodes...





new industrial pH system stresses reliability, flexibility

Beckman, world leader in pH instrumentation, introduces the all-new Model J pH System: compact transistorized analyzer, short, rugged electrodes, and accessory mounting assemblies. Here's continuous analysis equipment which provides reliability, flexibility, and convenience never before possible in industrial applications.

Check these Model J features, then see your Beckman Sales Engineer or Recorder Company Salesman for complete details, or write for Data File 46-9-06.

READOUT FLEXIBILITY. Available with both ma and mv output for use with any potentiometric or current recorders and controllers—or, with mv output only—recorder scale may be expanded to any 2 pH span full-scale. High or low alarm feature may be added.

SOLID-STATE ELECTRONICS. Assures reliability and saves long-term maintenance costs.

QUICK-DISCONNECT ELECTRODES. Short, rugged glass and reference electrodes feature capscrew for quick connect-disconnect of spade lug connectors. Speeds installation and replacement of electrodes.

DRIFT-FREE OPERATION. AC chopper amplification provides stability of 0.01 pH/24 hrs. over a −20°F to +122°F ambient temperature range.

HIGH ACCURACY AND SENSITIVITY. Output accuracy and meter sensitivity is ±0.02pH for full 0-14 pH or 0-±1400 mv range.

SIMPLIFIED MAINTENANCE. Plug-in components and circuits, rail-mounted analyzer chassis assure ease of maintenance, reduce downtime.

MINIMUM PANEL SPACE. Compact analyzer complements miniature current recorders, mounts in 6"x6" cutout.

ACCESSORIES FOR YOUR REQUIREMENTS. Variety of flow chambers and immersion and submersion units adapt Model J System to your present and future plant applications.

Beckman INSTRUMENTS, INC.

SCIENTIFIC AND PROCESS INSTRUMENTS DIVISION

Fullerton, Calif.

VISIT BECKMAN AT THE I.S.A. SHOW, LOS ANGELES, SEPTEMBER 11-15

←CIRCLE 106 ON READER SERVICE CARD

CIRCLE 107 ON READER SERVICE CARD

Now up to 500 PRV... the

HIGH CURRENT SILICON

Cathode terminal
. . . tin dipped to provide low resistance connection.

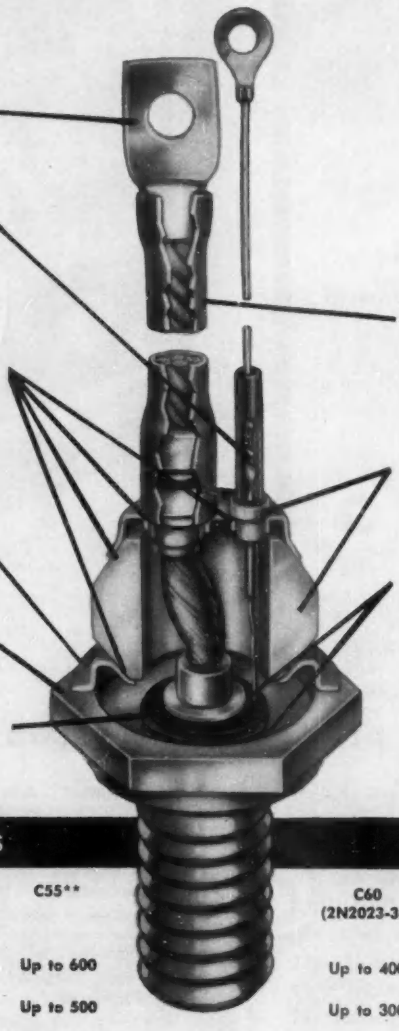
Gate
. . . reinforced welded connection provides maximum protection against rough handling and leakage.

Hermetic seals
. . . Kovar metal to matched oxide-bonded ceramic seals protect against thermal shock, cycling; enhance electrical stability, low leakage current.

Welded main seal
...maximum protection against housing leaks.

Steel hex
. . . maximum protection against damage from wrench.

Silicon pellet
. . . large area diffused junction provides conservative current densities, high surge current ratings.



Insulated lead
. . . Silicone rubber lead prevents shorting.

Ceramic insulation
. . . shock resistant, provides long creepage path which is ideal for severe industrial and military environments.

Hard soldered joints
. . . maximum protection against failures caused by thermal fatigue, cyclical loading; rugged tungsten back-up plates isolate junction from thermal stresses.

RATINGS AND CHARACTERISTICS

	C50 (2N1909-16)	C55**	C60 (2N2023-30)	C61	
Transient Peak Reverse Voltage (Non-recurrent < 5 millisecond)*	Up to 600	Up to 600	Up to 400	Up to 400	volts
Repetitive Peak Reverse Voltage (PRV)*	Up to 500	Up to 500	Up to 300	Up to 300	volts
Max. Allowable Repetitive Peak Forward Blocking Voltage (PFV)	600	600	400	400	volts
Minimum Forward Breakover Voltage (V_{BO})	500	500	300	300	volts
Peak One Cycle Surge Current (1 surge)	1000	1000	1000	1000	Amps
Max. Gate Current to Fire at 25°C	70	70	70	70	ma
Max. Thermal Resistance	0.4	0.4	0.4	0.4	°C/watt
Storage Temperature	−40 to +125	−40 to +125	−65 to +150	−40 to +150	°C
Stud Torque	150	150	150	150	In-Lbs.

* Rating assumes rectifier cell heat sink of less than 3.5°C/watt.
** C55 ratings identical to C50, except guaranteed turn-off time is 20 usec or less.

inside story of General Electric

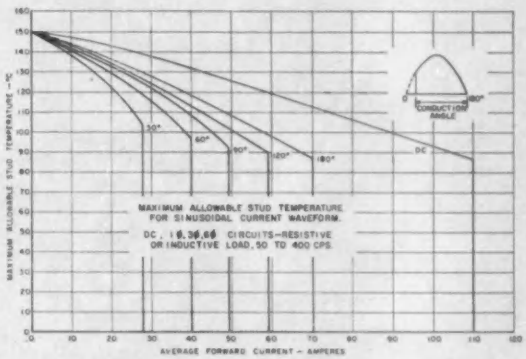
CONTROLLED RECTIFIERS

G-E HIGH CURRENT SCR's are three junction semiconductor devices for use in power control and power switching applications requiring blocking voltages up to 600 volts and load currents up to 110 amperes D.C. Series and parallel circuits may be used for higher power applications. Outstanding features of the most completely specified high current SCR's on the market today include:

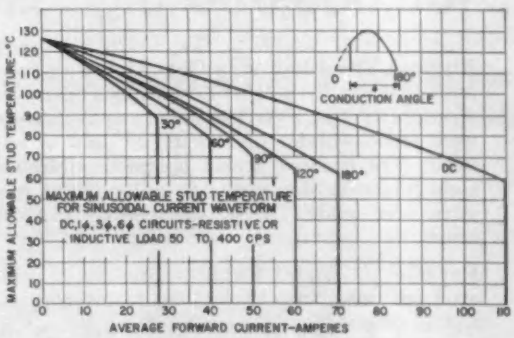
- Well defined, sensitive firing characteristics over the complete temperature range
- Up to 500 PRV for 2N1909-16 (C50) series
- Transient PRV ratings
- 100% testing of all specified electrical and thermal characteristics
- I^2t ratings permit easy fuse selection
- Operating temperature range available from −65°C to +150°C
- Available as inverter types with specified turn-off times

For complete technical data and applications information for your specific circuit requirements, call your G-E Semiconductor Products District Sales Manager. Or write Rectifier Components Department, Section 16I34, General Electric Company, Auburn, New York. In Canada: Canadian General Electric, 189 Dufferin Street, Toronto, Ont. Export: International General Electric, 150 East 42nd Street, New York 17, N. Y.





2N2023-30 (C60) and C61 Series



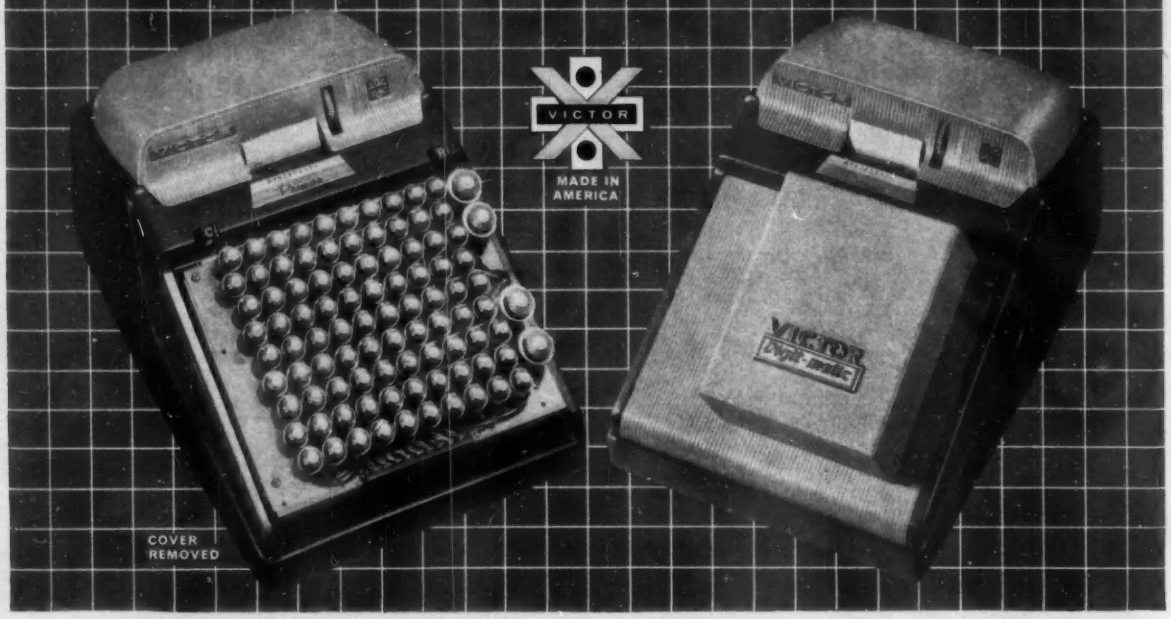
2N1909-16 (C50) Series

For fast delivery of High Current SCR's at factory-low prices, see your authorized G-E distributor

GENERAL ELECTRIC

CIRCLE 109 ON READER SERVICE CARD 109

PROVED ULTRA-RELIABLE VICTOR DIGIT-MATIC PRINTERS



160,000,000 digit impressions without failure

Rugged, Trouble-Free—Digit-Matics are specially built to stand the strain of continuous operation. In a durability test, over 160 million digit impressions were made without breakdown or need of adjustment. The machine tested operated continuously, eight hours per day until 160 million digit impressions were made. During this period only normal lubrication and cleaning were performed.

Parallel or Serial Entry — Automatic and unattended, solenoid-activated Digit-Matics print out alpha-numeric data from remote equipment. High speed parallel entry models accept up to 10 digits at a time, print up to 4 lines per second. Serial entry models accept 1 digit at a time, up to 11 per line.

Two-Color Printing — Positive values in black, negative values in red. Ideal for "accept-reject" sequences, testing applications, accumulating data from two sources on one Digit-Matic, and many other uses.

Adaptable to Your Specific Needs — Line includes listers, accumulators and calculators. Versatile units can handle degrees, minutes, seconds, fractions. Other modifications: superimposed keyboard for manual use, time readings, counters, etc.

Immediate Field Service — 70 factory service branches and service representatives in over 600 cities assure uninterrupted operation. Victor offers 30-day delivery on most Digit-Matics. Mail coupon now for product data and application information.

VICTOR
ELECTRONICS DIVISION

Victor Adding Machine Co., Chicago 18, Illinois
Victor Adding Machine Co., (Canada) Ltd., Galt, Ont.

Manufacturers of Digit-Matic Printers, Scanning Printers, Electrical Keyboards, and Digit-Matic Data Punches

Victor Adding Machine Co. CE-9
Chicago 18, Illinois
Send full information on Victor Digit-Matics.

My application is_____

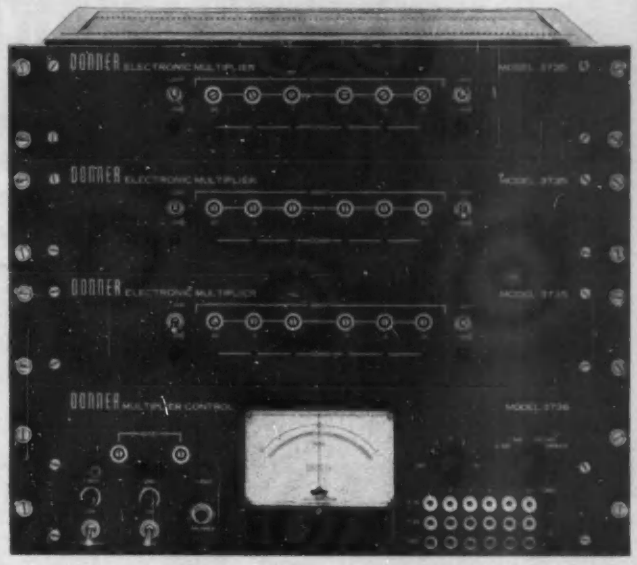
Name_____ Title_____

Company_____

Address_____

City_____ State_____

announcing...



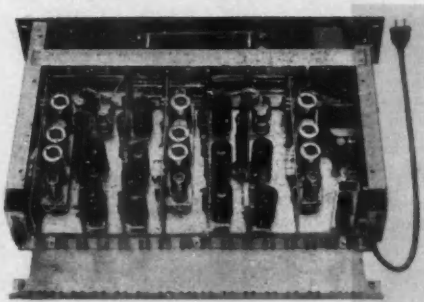
Illustrating three of the Donner Model 3735 Dual Electronic Multipliers (6 channels) associated with one Model 3736 Multiplier Control. This equipment provides 6 independent precision multiplier/divider channels, completely self-contained in only 15¾ inches of panel height.

the new Donner model 3735 dual electronic multiplier

with **0.01%**

SINGLE QUADRANT MULTIPLICATION & SQUARING ACCURACIES

Donner's new multiplier combines more most wanted features and high accuracies at a remarkably low cost. Check these features: **1.** 0.05% (FS) four quadrant multiplication accuracy. **2.** Completely compatible with all analog computers—no external power supplies or amplifiers required. **3.** Built-in division and square root operations. **4.** Modular construction with plug-in printed circuit cards. **5.** A 6 channel unit costs $3,800 or $633 per channel, compared to over $900 for comparable equipment.



The use of plug-in printed circuit cards in the Model 3735 Dual Multiplier assures adequate ventilation and easy access to all components. Shows 2 channel unit. Available in 2, 4, or 6 channels.

OTHER SPECIFICATIONS

INPUT Four independent voltages, X_1, Y_1, X_2, and Y_2 in the range of ±100 volts.

OUTPUT Two independent products, $-0.01X_2Y_1$ and $-0.01X_2Y_2$, in the range of ±100 volts at 10 ma maximum load current.

DRIFT Less than 100 mv over an 8 hour period.

NOISE Less than 100 mv, peak.

PHASE SHIFT Less than 1° at 100 cps.

ZERO ERROR With one variable = 0 and other ranging over ±100 volts, maximum error in product is only 40 mv.

DIMENSIONS Model 3736 Multiplier Control panel 5¼ x 19 inches.

Model 3735 Dual Electronic Multiplier panel 3½ x 19 inches.

Complete technical information on the Model 3735 Dual Electronic Multiplier is ready now. Call your nearby knowledgeable Donner engineering representative, or write Dept 21.

DONNER SCIENTIFIC COMPANY
A Subsidiary of Systron-Donner Corporation

888 GALINDO STREET • CONCORD, CALIF.
MUlberry 2-6161

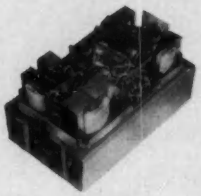
32

CIRCLE 111 ON READER SERVICE CARD 111

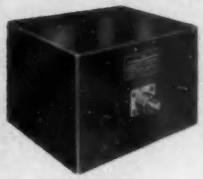
NAME THE CHARACTERISTICS* YOU WANT IN STATIC POWER



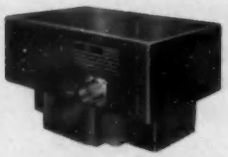
* Large Overload Capacity: 200%



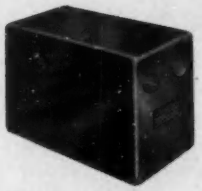
* Low Power Factor: 0.3 lagging to unity



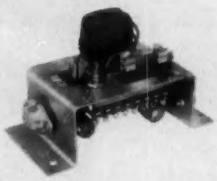
* Dual Output: Single or Three Phase



* Wide Temperature Range: −55° C to +125° C



* Accurate Frequency Regulation: 400cps. ± 0.25%



* High Efficiency: 85% minimum



* High Voltage Output: 150 KV



* Dual-Purpose: Charger and Inverter

...for • industrial telemetry systems • remote or emergency signalling, warning or measuring systems • automated machine tools • microwave communication equipment

... wherever circuit interruption cannot be tolerated

You probably would not need all of the design/performance characteristics listed above in a single inverter. But today, after a three-year, full-scale development program, Hamilton Standard static inverters offer a wider range of proven design and operating characteristics than any you can buy—individually and in combinations. This means that Hamilton Standard static inverters can deliver the extra reliability, long maintenance-free service and quick starts heretofore unattainable with rotary power supplies.

If your equipment calls for a power supply with exceptional reliability, tell us about your complete requirements. We can provide the inverter you need.

What are inverters . . . how, when and where to use them. A comprehensive aid for engineers. For your copy, write: Hamilton Standard Electronics, Broad Brook, Conn.



UNITED AIRCRAFT CORPORATION

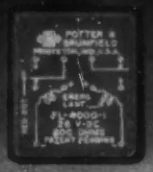
HAMILTON STANDARD DIVISION

ELECTRONICS

112 CIRCLE 112 ON READER SERVICE CARD

CIRCLE 113 ON READER SERVICE CARD→

a New and superior latching P&B relay



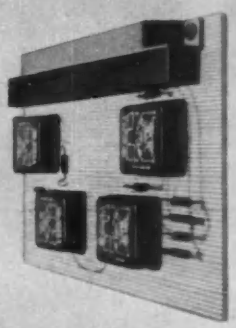
LIES FLAT FOR GREATER PACKAGE DENSITY, HIGHER PERFORMANCE



This DPDT, permanent magnet, latching relay is superior on these counts: (1) shorter height for maximum compactness between stacked circuit boards; (2) greater sensitivity (80 milliwatts); (3) better vibration resistance (30 g to 2000 cps); (4) better shock resistance (100 g).

Designated the FL Series, this relay meets all applicable sections of MIL-R-5757D, MIL-R-6106C and ABMA #PD-R-187.

Call your nearest P&B representative today for complete information about the whole P&B family of microminiature relays.



Printed circuit board using 4 FL relays was designed by the Martin Company, Orlando, as part of ground support equipment for a major missile project.

FL SERIES SPECIFICATIONS

Contact Arrangement: DPDT

Shock: 100 g for 11 milliseconds with no contact openings.

Vibration: .195; max. excursions, 10 to 55 cps, 30 g from 55 to 2000 cps. No contact openings.

Linear Acceleration: 400 g minimum with no contact openings.

Pull-In: 150 milliwatts, approx. (standard) at 25°C. coil temperature.

80 milliwatts, approx. (sensitive) at 25°C. coil temperature

Operate Time: 3 milliseconds max. at nominal voltage at 25°C. coil temperature

Dimensions: .465" high, 1.100" long, .925" wide

THERE'S A P&B CRYSTAL CASE RELAY FOR YOUR PROJECT



Diode in relay case is used for arc suppression in special applications. Four diodes form full-wave bridge rectifier for 400 cycles.



Non-latching or latching relays in conventional crystal cases with or without shoulder brackets, studs or mounting plates. All types of terminals are available.



Terminals spaced on .200" grids are available on all P&B microminiature relays. These carry a "G" suffix (SCG and SLG) and are .890" high, .800" wide, .400" deep, max.

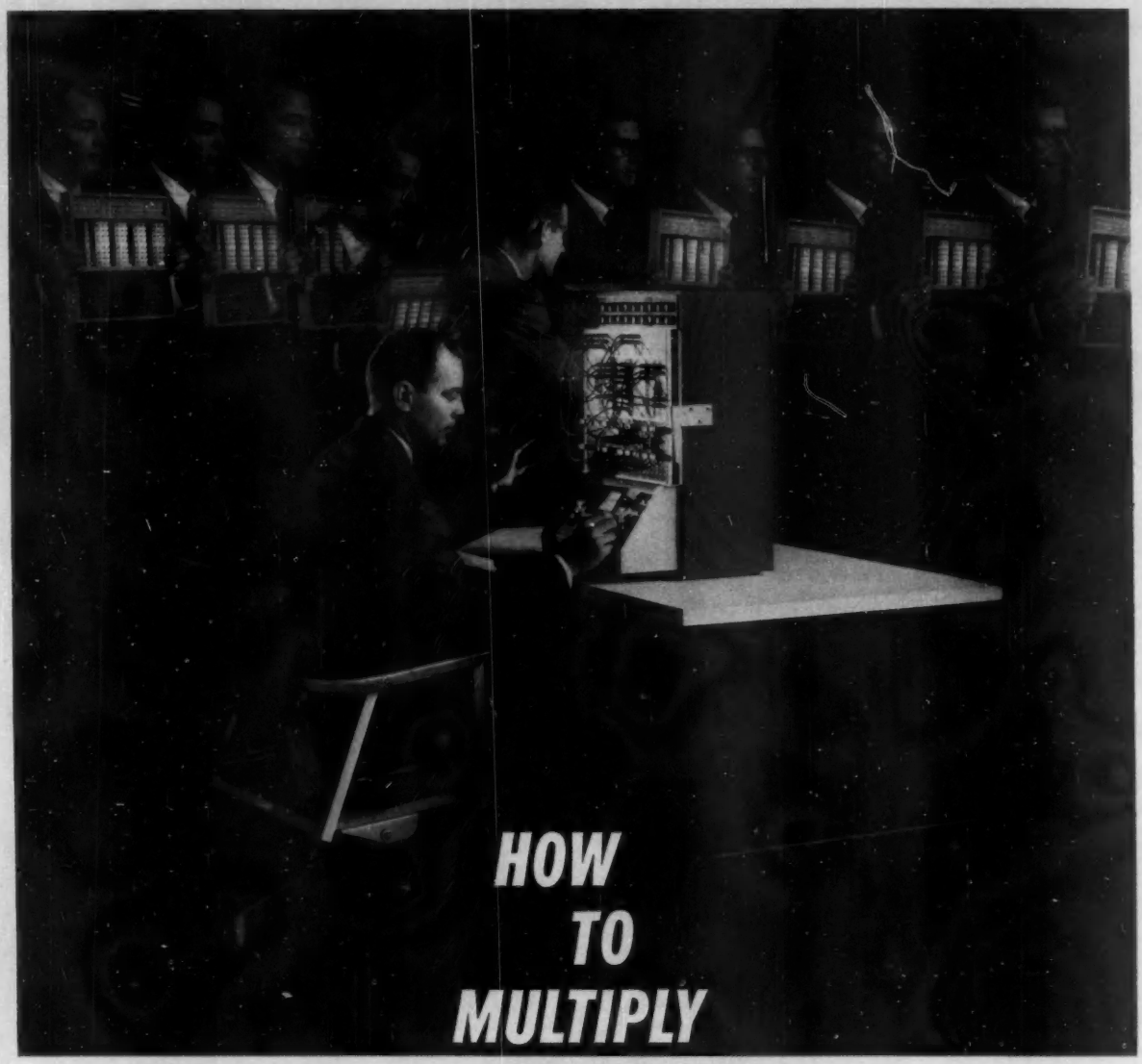
These 3 relays are shown slightly reduced in size.

P&B STANDARD RELAYS ARE AVAILABLE AT YOUR LOCAL ELECTRONICS PARTS DISTRIBUTOR

POTTER & BRUMFIELD

DIVISION OF AMERICAN MACHINE & FOUNDRY COMPANY • PRINCETON, INDIANA

IN CANADA: POTTER & BRUMFIELD, DIVISION OF AMF CANADA LIMITED, GUELPH, ONTARIO



HOW TO MULTIPLY ENGINEERS

One engineer and an EAI PACE TR-10 transistorized desktop analog computer can be the equal of several men limited to conventional design tools. The TR-10 multiplies the design capabilities of the most able engineer. One TR-10, equipped with a removable patch panel, will serve the needs of a roomful of engineers. This new patch panel permits pre-patching of programs away from the computer. It plugs into the computer instantly — valuable computation time is conserved. ■ *Versatility of the TR-10 is unequalled. Unique simplicity makes it excellent for students or engineers unfamiliar with analog techniques. Accurate to a tenth of one percent, the TR-10 performs admirably for the experienced user in 95% of routine engineering problems. And with High-Speed Repetitive Operation added, or with several units slaved to operate as one, the TR-10 meets the demands of many advanced applications.* ■ *For technical data on this almost infinitely versatile computer, write for Bulletin No. AC 934.*

EAI ELECTRONIC ASSOCIATES, INC. *Long Branch, New Jersey*

Leader in Analogics Analog/Digital Computers Data Reduction Process Control Instruments Computation Service

114 CIRCLE 114 ON READER SERVICE CARD



Solid State Devices

At a major U. S. company's research laboratories, administrators have just moved the physicists into an office right across the hall from the systems engineers and electronic equipment developers. The move, said the laboratory manager, will give the hardware-oriented engineers easier access to the fundamentals of physical science—primarily solid state.

Mechanize an effect

The R&D administrator told CtE, "Now when one of our research engineers runs into a problem in trying to accomplish a function in a new way, he talks to the physicists before he starts fiddling with a modification of some available hardware. Frequently they will be able to tell him, 'that sounds almost like what happens in impact ionizaton,' or some other phenomenon of science. A little more discussion may set the engineer off attempting to mechanize the phenomenon, and that is likely to lead to a radical new device."

Transistor list

One of the clearest trends in the rapid growth of the solid state industry has been this mechanization of the phenomena of physics in the form of a variety of devices now commercially available. The design is often tied closely to the method of manufacture. Variations in manufacturing can itself produce different devices. The transistor effect is a good example. A long list of devices stems from the mechanization of the transistor effect and methods of manufacture. Here's just a partial listing of transistor devices now available:

Name	Identifying Characteristic	Application
1. Point contact	First transistor, now almost obsolete	High frequency switching
2. Junction	Emitter and collector contacts are replaced by P-type and N-type material grown in a crystal	Amplifiers and oscillators for supply voltages of a fraction of a volt
3. Alloyed junction	Produced by alloying semiconductor material with another metal	Where low impedance to through transmission is required
4. Junction tetrode	Junction triode has second lead to base material	For high frequency switching and logic
5. Surface barrier	Thin germanium wafer is etched even thinner with metal contacts electroplated by etching jets	Improved high frequency response; improved gain bandwidth product
6. Drift transistor	Diffusing P-type and N-type material into a base material builds in an electric field across the base	Shortened transit time means better properties at high frequency
7. Filamentary transistor	N-type material is shaped like a filament with emitter at one end, collector at the other	Pulse storage in computer memories
8. Fieldistor or Unipolar	Operates on only one kind of charged carrier because of large rectifier barrier	Amplifier much like a vacuum tube
9. Avalanche	Junction transistor with low breakdown voltage so large current flows for slight increase in reverse voltage	To replace gas tube circuits
10. Unijunction	Junction terminal floats in negative resistance region	In integrated circuit devices

Question: Can circuits be simplified with increased reliability?

Answer: Yes! With the Tung-Sol **dynaquad** ***—a four-layer device.***

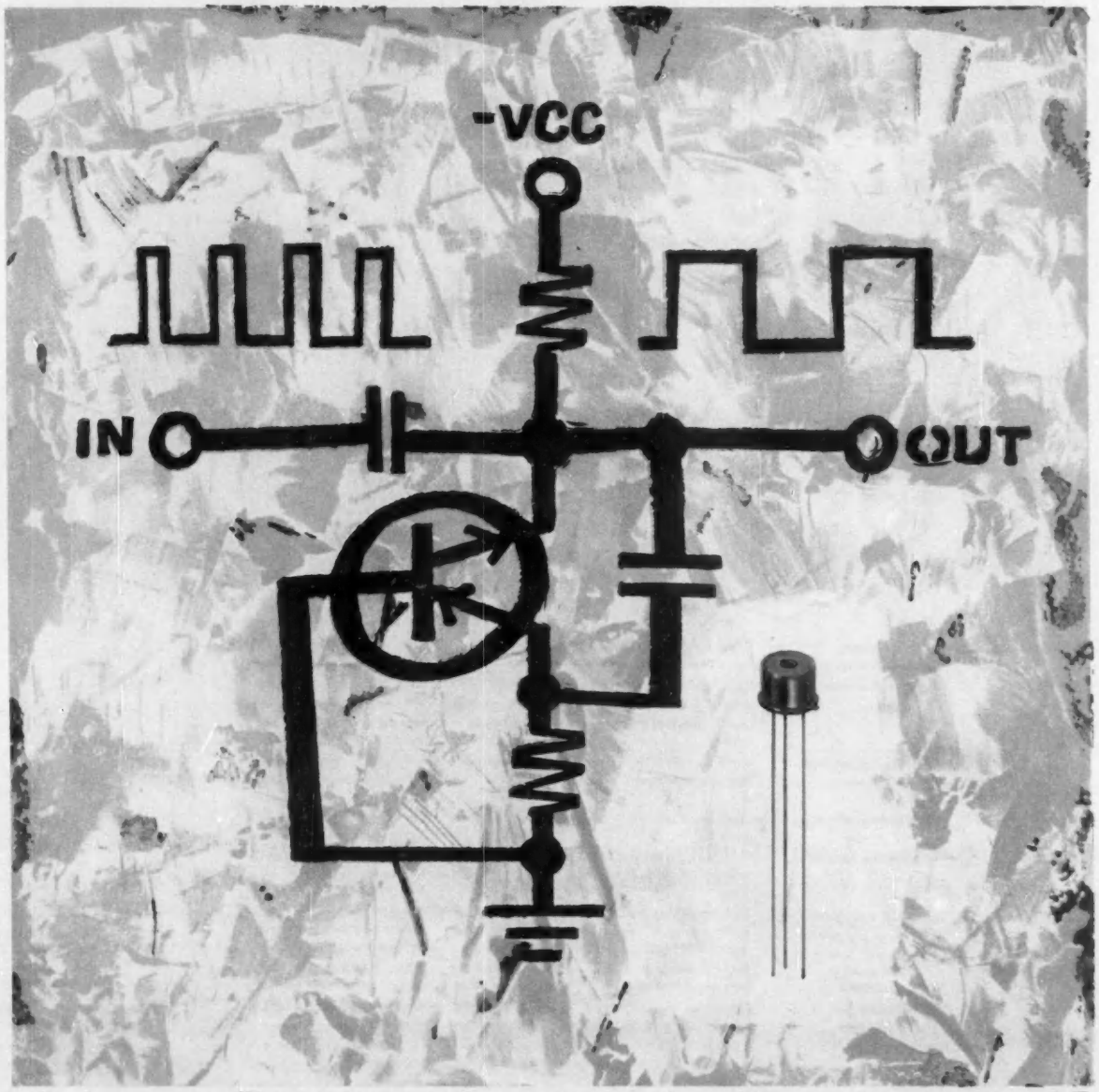
Dynaquad is a PNPN bistable transistor which makes it possible to accomplish flip-flops, binary counters, solid state relays, shift registers and various forms of logic with a saving of one-third to one-half in components and space. In many circuits it directly replaces a number of transistors and their associated components. In others it permits use of transistor techniques where they previously had not been practical.

Finding its chief application in the fields of computation and control, the Dynaquad is a new circuit tool for small signal switching, driving and pulse-forming applications.

Tung-Sol's applications engineers have developed 100 kilocycle shift registers and a 1 megacycle reversible ring counter, using amazingly few components. Circuit diagrams and complete design information are available on request. With great simplicity, bistable, monostable and astable multi-vibrators can be fabricated, using the Dynaquad. One such example is shown below. You are also invited to discuss any special questions you may have with Tung-Sol's applications engineers. Tung-Sol Electric Inc., Newark 4, N. J. TWX:NK193

TECHNICAL ASSISTANCE AVAILABLE THROUGH: Atlanta, Ga.; Columbus, Ohio; Culver City, Calif.; Dallas, Tex.; Denver, Colo.; Detroit, Mich.; Irvington, N.J.; Melrose Park, Ill.; Newark, N.J.; Seattle, Wash. In Canada: Abbey Electronics, Toronto, Ont.

TUNG-SOL®



Two resistors, two capacitors and one Dynaquad make a bistable.



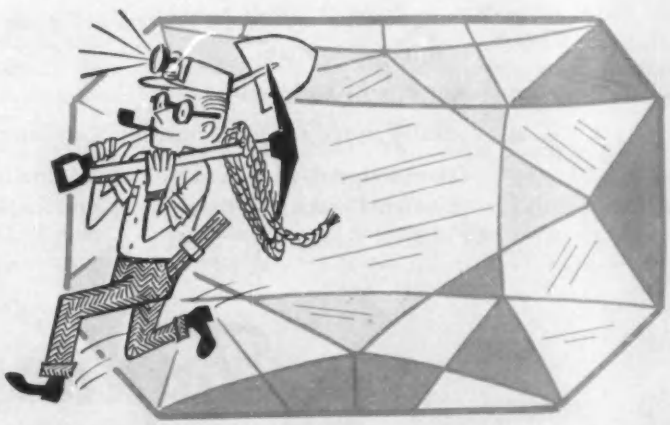
These by no means exhaust the list. In addition there are the analog transistor, Hook collector transistor, remote base transistor, punchthrough-avalanche transistor, emitter tetrode, unipolar tetrode mesa transistor, and conjugate transistor.

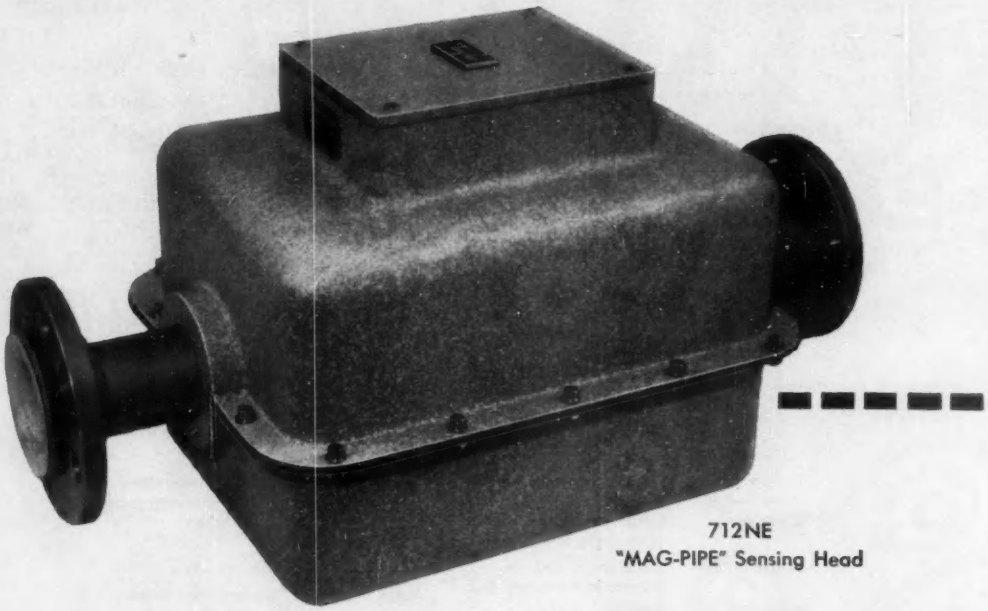
Device explosion

When this approach to device design is applied to all the solid state phenomena discussed in the article on pages 58-69, the list of devices becomes extremely long, and grows continually at an incredible rate with newly completed devices. Here are some of the more interesting and important devices and the main solid state phenomena responsible for their operation. In most, several effects take place; the one listed is responsible for the major characteristic of the device.

Device	Phenomenon	Device	Phenomenon
Thermistor	Large temperature coefficient of resistivity of semiconductors	Thermoelectric cooler	Peltier effect
Magnetoresistor	Resistance of conductor changes in a magnetic field	Power cell	Seebeck effect
Hall effect generator	Hall effect voltage	Solar cell	Semiconductor photoconductance
Varistor diode	Semiconductor resistance depends on voltage, current, or polarity	Star detector	Semiconductor photoconductance
Nonlinear resistor	Same as varistor diode, but current may flow in either direction	Photodiode	Semiconductor photoconductance
Strain gage	Semiconductor resistance varies with force on material	Rayescent element	Electroluminescence
Piezoelectric element	Ferroelectricity and piezoelectricity	Light transistor	Semiconductance and electroluminescence
Cryotron	Superconductivity	Laser	Pumped ion change in energy level and radiation resonance
Cryosar	Superconductivity	Tunnel diode	Tunneling
Impact ionization switch	Low temperature impact ionization	Tunnel transistor	Transistor effect and tunneling
		Silicon controlled rectifier	Semiconductance

Clearly, the future of the solid state device business is tied closely to the mechanization of solid state phenomena and methods of manufacture.





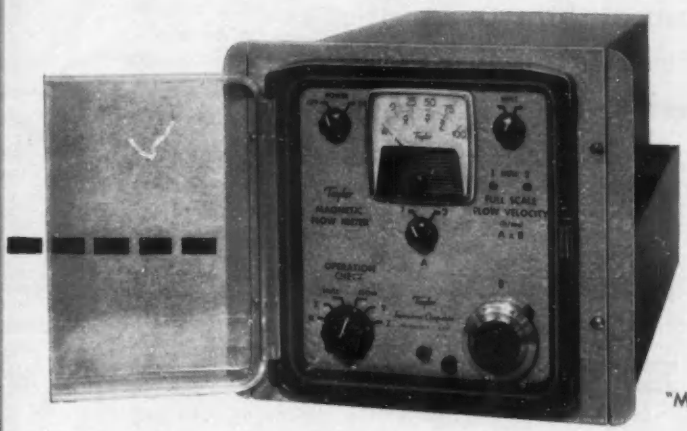
712NE
"MAG-PIPE" Sensing Head

Taylor presents a **MAGNETIC**

OUTSTANDING FEATURES

- High accuracy—½% of full scale on most ranges.
- Full scale velocities as low as ½ ft./sec., at only slightly reduced accuracy.
- Conductivity range—as low as distilled water.
- Rangeability—½ to 30 ft./sec. full scale calibration, continuous vernier adjustment.
- Amplifier—solid state.
- Ideally suited for long transmission runs to a central control panel.
- Output signal—1-5 ma DC into any load from 0-3000 ohms. (Electro-Pneumatic Transducer or TRANSCOPE Electronic Control System).

Taylor Instruments



717TE
"MAG-PIPE" Transmitter

FLOWMETER TRANSMITTER WITH 1/2% ACCURACY

The new Taylor "MAG-PIPE" Magnetic Flowmeter Transmitter is a high quality, high performance transmitter with an toutput signal of 1-5 ma suitable for transmission over long distances. It can therefore be used with miniature receivers and controllers in central control rooms.

It is designed to measure flow of fluids with an electrical conductivity as low as that of distilled water. It is ideally suited for very low flows, viscous liquids and liquids containing suspended solids, since the flow is not in any way restricted by the primary element.

The "MAG-PIPE" sensing head is mounted in the flow line. It comprises a flow tube, an AC magnetic circuit and two electrodes. The sensing head housing is "hose-down proof" (explosion-proofing optional), and has Van Stone type flanges for easier, faster installation.

The transmitter employs *solid state* components, being fully transistorized for long-term reliability. It is standard in fixed-range form, in which case calibration is factory set at the desired range. Optionally available with a full-scale vernier adjustment on two ranges. A built-in output meter doubles as a circuit checking device.

The "MAG-PIPE" Flowmeter Transmitter is in production. Consult with us on your difficult flow measurement problems. See your Taylor Field Engineer or write for **Bulletin 98418.** Taylor Instrument Companies, Rochester, N.Y., and Toronto, Ontario.

MEAN ACCURACY FIRST

Solid state devices and systems give control systems capabilities that cannot be duplicated in any other way. The application of solid state phenomena in control is the one most significant development of the past decade in every area of control—aerospace, machinery, and process control.

What Solid State Means

TO CONTROL ENGINEERING

LEWIS H. YOUNG
Control Engineering

Solid state developments ". . . will make possible functions which are not now capable of being performed, will offer the potential of large increases in reliability, and can achieve reductions of size, weight, and power consumption of very large proportions". Thus ends a report completed earlier this year by the U.S. Navy's highly regarded Office of Naval Research. It sums up what solid state means to control engineering: it will impart performance characteristics that cannot be equalled any other way to equipment in every part of the control loop. If there is one development that can be said to be the *one most significant* of the last 10 years—in aerospace, in machinery, and in process control—that development would have to be "solid state".

A solid state inertial guidance system. A nuclear digital pressure transducer. And a method of data transmission whose theoretical capacity approaches 80 million television channels. These developmental projects illustrate how radically solid state phenomena are likely to change the measurement and control scene. And these are not pipe dream creations. Engineering is well along in these and hundreds of other startling projects.

Almost anything that happens to a solid can be considered a solid state effect. But the phenomena that are of interest to control engineers are rooted in the atomic and molecular structure of materials and depend on the conduct of charged particles. In this issue of CONTROL ENGINEERING, solid state phenomena are restricted to those effects which result when electrons or ions change energy levels or from an unusual configuration of energy levels brought about by environmental conditions.

In the article that starts on page 122, Prof. A. G. Milnes has put the mechanisms that explain the most significant phenomena in engineering terms, breaking them out of the jargon of the physicist. From this article, one other restriction for defining solid state phenomena emerges: the material must have a repetitive structure—atoms arranged with periodicity. In most materials this means crystal structure.

Significant phenomena

The phenomena that hold the most promise for control engineering are:

Semiconductance—the ability of materials that are in between good insulators and good conductors to carry electric current. They lead to reliable, miniaturized circuit components to handle both information and power signals.

Tunneling—the passage of charged particles *through* energy barriers which are too high for the particle to climb over by normal processes. Tunneling takes place at very high speeds, and devices based on this effect operate at very high speed and with very low power.

Electroluminescence—an ac current applied to a phosphor stimulates the material to emit light. It can be used in display devices, in light amplifiers, and in performing logic when the functions of logic and display have to be combined.

Ferromagnetism—a property of materials which affords spontaneous magnetization. New studies prove that this property is not restricted to materials in the iron family. The effect is used by thin film

memories and logic elements and magnetic devices such as multiple aperture cores.

Ferroelectric effects—an electrical analogy to ferromagnetism; materials exhibiting this effect polarize spontaneously in an electric field. The phenomenon has been applied to build experimental logic and memory units.

Seebeck effect—known for over fifty years as the principle behind the operation of a thermocouple. When two dissimilar metals are joined in a closed circuit and the junctions are held at different temperatures, a voltage is generated. In semiconductors it has led to the development of large thermoelectric power supplies for isolated industrial installations and for space vehicles.

Peltier effect—an inverse Seebeck effect. When a voltage is passed through a closed circuit made of two dissimilar materials, one junction heats and the other cools.

Superconductivity—that materials cooled to temperatures around 10 deg K lose all their resistance has been known for decades as superconductivity. But only recently has this effect been considered more than a scientific curiosity.

The solid state loop today

Much of this sounds like a prospectus of developments to come. But the application of solid state phenomenon is for today too. It is now perfectly plausible to speak of a solid state control loop, with solid state devices performing every one of the control functions.

The articles on pages 122 to 182 illustrate how a control engineer can apply solid state techniques and equipment today.

The first section talks about measurement. Some of the most exciting developments in solid state are taking place in the area of new measurement techniques and devices. For example, the Hall effect (page 138) is now finding its way into industrial measurement of almost every variable—flow, pressure, and temperature. New solid state detectors of radiation—visible, infrared, or nuclear—have capabilities far superior to previous devices (page 142). And solid state strain gages (page 134) give miniaturization and accuracy unheard of fifteen years ago.

In data transmission, the solid state revolution has resulted in startling improvements in signal modulation equipment with transistorized circuitry. Last year's demonstration of the laser, which generates coherent light, opened an even more spectacular possibility for data transmission. Light provides a medium that can carry 1,000 times as much information as microwaves (page 147).

In decision-making, solid state devices contribute to faster operation, more reliable devices, and greater capability. Their reliability has sold electronic equipment to industrial users as no other characteristic has. In control engineering, logic and memory are playing a growing role as industry moves to more automatic systems. The unique problems of memory in a control system are detailed in the article starting on page 150. Similarly, the application of logic in control is quite different from its use in computers. The article on page 156 introduces some new approaches to control logic, innovations made possible by solid state devices.

Many instruments based on solid state phenomena used to be limited to very small power outputs, restricted to handling information signals. Such a restriction no longer applies. The power transistor and the silicon controlled rectifier are superb methods of modulating power—and both are commercially available now. The article on page 163 compares their performance and application.

Thermoelectric generators and solar cell power supplies (page 173) have become important because of advancements in space technology. They are light, self-contained units that can generate kilowatts of electric energy. Similarly, thermoelectric coolers (page 178) are commercially available.

Display, the final function of the control system, has been slower to reap the benefit of solid state phenomena. Many electronic printers have been redesigned to use solid state circuits, and development of a solid state cathode ray tube is under way. But electroluminescence offers the most promise as an extremely flexible display (page 180).

Serendipity

The application of solid state phenomena to control has produced some unexpected byproducts that may be as valuable as the prime effort. For example, the production of very pure materials for semiconductor devices, such as diodes and transistors, led to the discovery that pure semiconductors have exceptional optical properties in the infrared region. As a result, germanium and silicon lenses in infrared devices have improved sensitivity as much as sixteen times. It is impossible, of course, to predict what other unexpected benefits will accrue.

The area that promises to have the greatest impact is so-called molecular electronics, the building of one piece systems and subsystems. The article on page 183, written by Harrell Noble, who has spearheaded molecular electronic development for the Air Force, shows what control engineering can expect from this new development.

The future of solid state in control is clear. It is summed up neatly in the ONR report, which predicted: ". . . The emphasis in military solid state electronics in the future will not be on the development of equivalent or better replacements for present conventional electronic components, but in a basic change in system design, circuit design, and device fabrication".

Atoms, molecules, and crystals have very many energy levels at which an electron can be located. Either the configuration of energy levels or an electron changing energy levels is the basis for most solid state phenomena. To understand how and why solid state devices work, an engineer needs to know a few essentials of modern physics, wave mechanics, and some statistical mechanics. The author attempts a brief explanation of the most significant phenomena.

EXPLAINING Solid State Phenomena

A. G. MILNES, Carnegie Institute of Technology

In a semiconductor, current flows because electrons normally bound to the atom in one energy band have been stimulated thermally so they jump an energy gap to another band and become free electrons. The explanation of how all solid state devices work stems from an understanding of the energy levels of electrons as they exist in atoms, molecules, and crystals. An infinite number of energy levels can exist, and, just as important for solid state phenomena, many levels are forbidden.

The rules for setting up energy levels were derived from the study of matter and energy. Some concepts that help an engineer understand solid state phenomena are these: the dual nature of radiation—sometimes it acts as a wave and sometimes as a particle or quantum—wave mechanics, which defines the conduct of a particle when it acts like a wave; and the application of statistical mechanics to the well-known first and second laws of thermodynamics.

FIRST, SOME BACKGROUND

Energy levels are tied closely to the structure of material. Radiation has been the physicist's most potent tool for disclosing secrets of the structures of atoms, molecules and crystals. Interference experiments have established the wave characteristics of radiation. From spectroscopy has come a picture of the atom as a positively charged nucleus with electrons circulating around it in circular, elliptical, or more complicated orbits. The orbit, angular momentum, and spin of the electron, identified by integers called quantum numbers, determine its energy level. Figure 1 shows the energy level diagram for a moderately heavy element such as zinc. When an electron moves from one level to another as shown, X-rays are generated. Since the quantum number n is an integer that can have all values to infinity, an infinite number of energy levels are possible.

Electromagnetic radiation also exhibits characteristics that are usually associated with a particle. When radiation impinges on a metal target, for example, it can dislodge electrons. The way this takes place demonstrates the corpuscular or particle nature of radiation. Electrons emitted by the bombardment of radiation whose frequency is ν cannot have a kinetic energy greater than eV_o, where V_o is a voltage that is characteristic of the metal and e is the charge of the electron. When V_o for two materials is plotted against frequency of bombardment, the resultant curves are two straight lines with the same slope. Figure 2B. Value of the slope is h/e where h is an important universal constant called Planck's constant* and e is the electron charge.

From the plot of Figure 2B, the kinetic energy of the dislodged electron can be expressed as

$$eV_o = h\nu - e\phi \qquad (1)$$

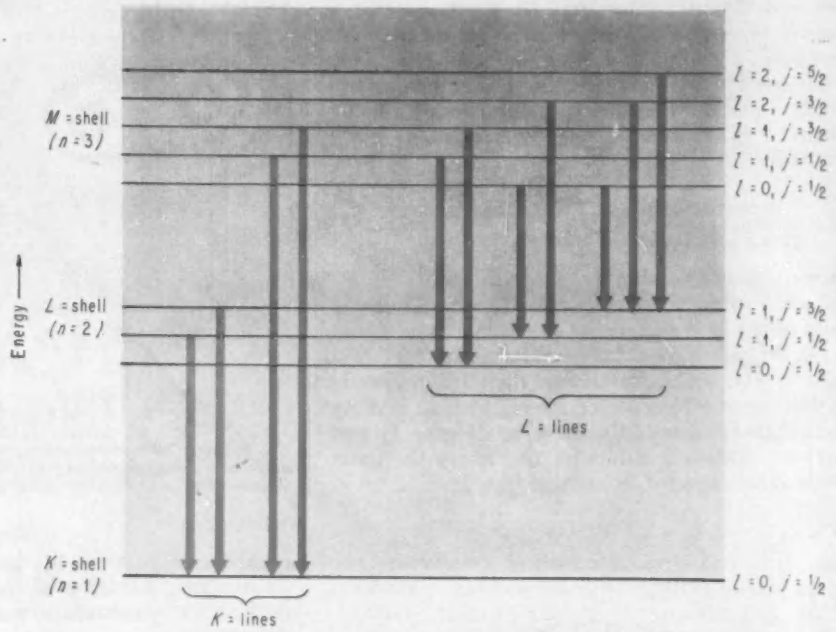


FIG. 1. Simplified energy level diagram for a moderately heavy element shows how X-rays originate. As orbital electrons change energy levels, transitions indicated in color, X-rays are emitted. Quantum numbers, n, l, and j, establish selectivity rules for allowable transitions: $\Delta l = \pm 1$, $\Delta j = \pm 1$ or 0.

PHOTOELECTRIC EMISSION

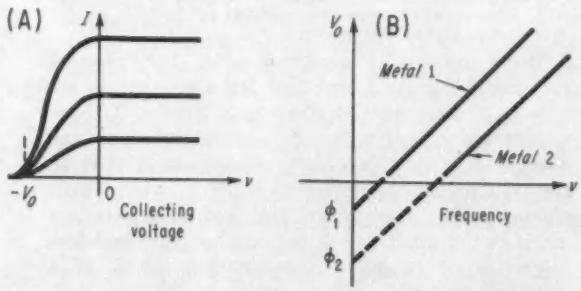


FIG. 2. (A) Plot of current emitted versus voltage applied to collect photoelectrons. Frequency of light was constant for all three curves, while illumination intensity varied in each. Higher intensity produces higher current. (B) Plot of V_o versus frequency is a straight line for any metal. The slope of such curves is the same for all metals: h/e.

Thus the energy of the emitted electron is equal to the energy of a photon (or quantum) of bombarding radiation less the energy required to pull the electron from the metal—the latter is called the work function.

Four significant facts about this phenomenon have been observed:

1) No photoelectrons are emitted unless the incident light has a frequency at least equal to a minimum threshold value. The threshold energy of the radiation, $h\nu$, is equal to the work function.

2) When a metal plate is illuminated by radiation, the number of photoelectrons emitted per unit area is proportional to the intensity of illumination.

3) When a plate is illuminated by a monochromatic source of radiation, the speed of emitted photoelectrons varies from extremely small values to a maximum. The maximum speed is independent of the intensity of illumination but increases with an increase in frequency of the bombarding radiation.

4) Photoelectrons are emitted at once, as soon as illumination begins, even when the intensity is so weak that, according to classical wave theory, an atom would have to absorb energy for days to impart enough energy to emit an electron.

Wave mechanics

After Einstein had proposed the quantization of light photon energy (Equation 1), a French physicist, de Broglie, introduced a concept in 1924

*In 1900, during a study to explain the distribution of radiation emitted by a black body, the German physicist Max Planck assumed that the source radiated energy intermittently, in packets or quanta, instead of continuously as had been believed. He suggested the equation:

Energy = constant × frequency of the radiation

He denoted the constant with the letter h and found its value to be 6.625×10^{-34} joule sec. This assumption started quantum mechanics.

that was almost as startling. He suggested that a particle of very small mass, such as an electron, behaved like a photon and acted like a wave in many instances. He proposed that the particle has a wavelength equal to Planck's constant divided by the particle's momentum:

$$\lambda = \frac{h}{mv} = \frac{h}{2mE_k} \tag{2}$$

where m = mass of the particle
E_k = kinetic energy.

From this relationship an electron with 150 eV (electron volts) energy has a wavelength of about 1 Angstrom (10^{-10} meters).

De Broglie's theory led to the development of a fundamental wave equation and the wave mechanics to describe the behavior of atomic particles. Wave mechanics deals with a wave pulse (Figure 3) and produces statistical results in contrast to the finite single value expected in classical physics.

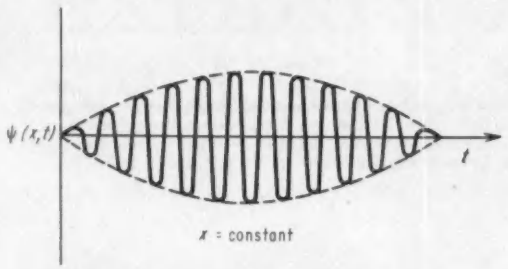


FIG. 3. Representation of a particle by a wave pulse is constructed in wave mechanics.

In 1926, Schrödinger proposed the generalized wave equation

$$\frac{\partial^2\Psi}{\partial x^2} = \gamma \frac{\partial\Psi}{\partial t} \tag{3}$$

where Ψ is the wave function. This equation seems less strange if it is compared to other well-known differential equations in physics. For example, the equation for a wave on a string has the form:

$$\frac{\partial^2 y}{\partial x^2} = \gamma \frac{\partial^2 y}{\partial t^2}$$

where the dependent variable (y) is a function of x (position) and t (time).

Schrödinger's equation replaces the Newtonian equation $F = ma$ of classical physics to describe the motion of an atomic particle. The dependent variable Ψ has no physical significance itself; it is defined in terms of $|\Psi^2|\,\Delta V$. The definition: $|\Psi|^2\,\Delta V$ is proportional to the probability that the electron will be found in the volume ΔV.

There are several reasons why probability and statistics are not only satisfactory but desirable methods for describing the motion of electrons. Normally the engineer is interested in very large

ENERGY GAPS

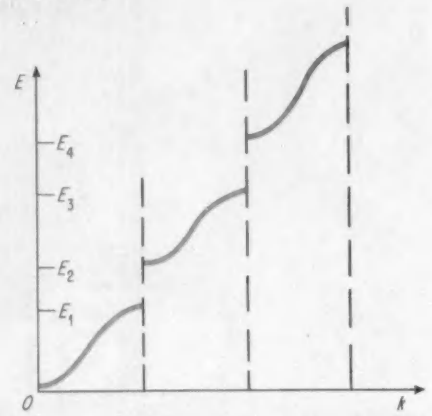


FIG. 4. Energy curve plotted versus wave function vector number shows allowable levels and gaps in which levels are not allowed. Solution of the wave equation forbids modes of oscillation in the gaps.

numbers of particles so that statistical results are meaningful. For example, in a small current of only 0.01 microamp, 10^{12} electrons pass in one minute.

In addition, a question such as "where is an electron precisely?" has no physical meaning. The Heisenberg uncertainty principle states that there is a finite limit of accuracy in the measurement of momentum and position. This limit is given by the expression:

$$\Delta p \Delta x \geqq h$$

where Δp = error in measuring momentum
Δx = error in measuring position
h = Planck's constant

Wave mechanics made obsolete the physical picture of the atom that first led physicists to energy level diagrams like the one in Figure. 1. Now quantum numbers n, l, and j are mathematical consequences of the boundary conditions applied to the wave equation instead of being associated with electron orbit, momentum, and spin. The numbers occur in the same way as the fundamental and harmonic notes occur in the simple analysis of a stretched string.

Energy levels in molecules and crystals

In a molecule or crystal, the assignment of energy levels is complicated by the interrelations of electrons. The procedures of wave mechanics locate these levels. To understand the mathematical procedures, consider the generalized solution of the Schrödinger wave function:

$$\Psi = \exp\left(\pm ikx \pm \frac{iE}{h^2}t\right)$$

It represents a standing or traveling wave, depending on the precise form. With a simple one dimensional boundary condition such as a square well of potential energy, the wave number vector, k, has a set of

ENERGY BAND SPLITTING

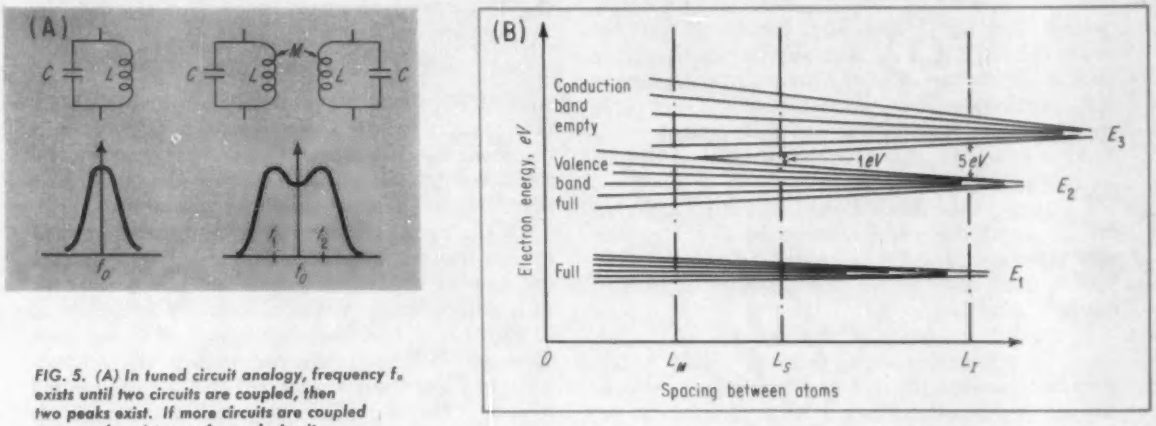


FIG. 5. (A) In tuned circuit analogy, frequency f_o exists until two circuits are coupled, then two peaks exist. If more circuits are coupled more peaks exist—one for each circuit. (B) Energy level diagram for a six atom arrangement shows level splitting.

allowed values that correspond to discrete energy values for an electron under such conditions.

In a crystal that has a regular array of nuclei, the potential energy is a periodic function of x so the wave function becomes

$$\Psi = (\exp ikx)u_k(x)$$

where

$$u_k(x + a) = u_k(x)$$

and a is periodic distance between nuclei. When the equation is applied to a three dimensional potential energy field in a crystal and the wave function energy E is plotted as a function of wave number k, gaps exist in the energy scale (Figure 4). Thus the crystal potential field keeps an electron from having a mode of oscillation (wave function) corresponding to an energy between E_1 and E_2, or between E_3 and E_4, etc., in Figure 4. Since there are many allowed modes of oscillation, between E_2 and E_3, for example, this spread is called a band of energy states. The discrete binding energy of an electron in a single atom is changed into a band of allowed binding energies in the crystal.

A crystal may have many allowed energy bands, the number depending on the atomic structure. But the lowest bands are always filled with an electron at every possible energy level. The highest filled band is called the valence band and the lowest empty band is called the conduction band. The gap between the valence and the conduction band is called the forbidden energy gap.

The concept of bands of energy levels helps explain why a crystal is an insulator, a semiconductor, or a metal, and is useful in understanding how many solid state phenomena take place. One interesting feature of the energy band is its splitting, a phenomenon that is the result of the binding of electrons in molecules.

There is an analogy in electronic circuits that helps engineers understand level splitting. If two LC circuits (as in Figure 5) are tuned to the same frequency and brought close together so that mutual coupling occurs, frequency peaks develop. When each circuit is tuned to frequency f_o, peaks f_1 and f_2 develop. If six identically tuned circuits were coupled, six distinct frequency peaks would appear—all very close in value. If n circuits were coupled, n peaks would appear. Experiment shows the greater the coupling the greater is the frequency spread covered by the peaks.

The allowed electron orbits in an atom are analogous to the tuned circuit condition. An electron orbit has an energy level associated with it. If six atoms are brought close together, the allowed electron orbits will adjust themselves so that six distinct energy levels occur instead of the original single state. Figure 5(B) demonstrates this. The closer the atoms are brought together, the greater is the spread of the splitting.

In a crystal that has 4×10^{22} atoms per cc, the energy bands would have 4×10^{22} separate allowed energy levels per cc. The lattice spacing determines the spread of these energy bands. Spacing depends on a balance of crystal energies, such as the repulsion between the nuclei or quantum mechanical attractive energies, an effect caused by electron sharing in covalent bonding (a form that pairs of electrons take in certain structures). The size of the gap between the bands determines the electrical qualities of the material. For example, in a metal such as copper there is no forbidden energy gap—the conduction band and valance band overlap; in a semiconductor such as germanium the gap is about 1 electron volt; and in an insulator it is many electron volts.

If in the isolated atom of a crystal structure the levels E_1 and E_2 contain electrons in the ground state condition, the crystal energy bands E_1 and E_2 have an electron in each allowed energy state. The

bands are said to be fully occupied. If the lattice spacing were L_1 (Figure 5B), the energy gap between the top of the E_2 band and the lowest empty state at the bottom of the E_3 band is so considerable that electrons agitated thermally would not gain enough energy to jump the gap to the empty conduction band. In this case the material would be an insulator.

Electrons in the bands E_2 and E_1 are not available for the conduction of electricity because the lack of empty energy states does not permit them to pick up energy and produce a net flow when an electric field is applied.

If the lattice spacing is smaller, such as L_3, the energy gap becomes of the order of 1 eV. A few electrons, perhaps 10^{11} out of 4×10^{22} per cc, may acquire modes of oscillation corresponding to energy levels in the E_3 band. When an electric field is applied to this material, these electrons can move to adjacent empty levels. The 10^{11} conduction electrons means the crystal has a moderate resistivity—of the order of a few thousand ohm-centimeters—at room temperatures. It is a semiconductor.

If the lattice spacing is still smaller, such as L_M, the bands E_2 and E_3 overlap. Many of the electrons in band E_2 can move to the numerous empty states in E_3. The crystal is then a good conductor.

Fermi probability

One other tool is helpful in explaining how solid state phenomena occur. That is the Fermi probability of occupancy of energy states. It is expressed by the relation:

$$f(E) = \{[\exp (E - E_o)/KT] + 1\}^{-1} \qquad (4)$$

where $f(E)$, the Fermi probability, is the probability that an electron will occupy the energy state E; K is the Boltzmann constant (a number given by the ratio of the universal gas constant and Avogadro's number); and T is the absolute temperature.

E_o, the Fermi level or Fermi brim, is determined by the number of electrons per unit volume and the number of quantum states per unit volume in each energy range. When Equation 4 is plotted as in Figure 6, the physical significance of E_o becomes apparent. If $E < E_o$, the first term in the denominator of Equation 4 approaches $e^{-\infty}$, which is equal to zero. Therefore $f(E)$ approaches the value 1, when $E < E_o$. If $E > E_o$, the denominator approaches e^{∞} and $f(E)$ approaches zero. From Figure 6, it can be seen that the Fermi probability $f(E)$ goes from 1 to 0 when E changes from E_o minus a few KT to E_o plus a few KT. At energy E_o, the probability of occupancy of states is one half.

The Fermi level is most important when two solids are in contact. For example, it explains the existence of the contact potential when two dissimilar solids are in contact, because E_o in one must equal E_o in the other at equilibrium.

With these fundamental concepts in mind, you can begin to explain what happens in those solid state phenomena that are of interest to engineers.

EXPLAINING THE SOLID STATE PHENOMENA

Almost any occurrence in a solid material can be called a solid state phenomenon. But those that are the newest and hold the most promise for the control engineer can be classified into six major groups:

1) semiconductor phenomena
2) photoelectric and electroluminescent
3) ferromagnetic
4) piezoelectric and ferroelectric
5) thermoelectric
6) cryogenic phenomena

On pages 115 and 117, practical devices are tabulated against the phenomena that make them possible.

SEMICONDUCTORS

Semiconductors are a class of substances that have a resistivity between that of insulators and conductors — from 10^{-4} to 10^{4} ohm-meters.

In a metal, conductivity depends on the electron density in the material and the mobility of the electrons. Mobility is limited by scattering: 1) scattering by the lattice vibrations and 2) scattering by impurity atoms and other lattice imperfections. Only electrons with an energy close to the Fermi energy level E_o can contribute to conduction. If E is very much greater than E_o, the Fermi probability is close to 0 and that means the energy levels are empty—and thus cannot contribute to conduction. If E is very much less than E_o, the energy levels are all filled and also do not contribute to conduction.

Thus, conduction in a metal stems from a few free current carriers and a large number of unoccupied energy levels close to the occupied energy levels.

Intrinsic semiconductors

If the occupied energy levels are not close to the empty energy levels, the material is an insulator. At sufficiently high temperatures, electrons in the filled band may gain enough energy from scattering to move to the conduction band so that conductivity increases strongly with an increasing temperature. Insulators that have this property are called intrinsic semiconductors and include such materials as silicon and germanium.

An interesting characteristic of these materials is that two kinds of carriers are involved with current flow. One type is electrons in the conduction band. For every electron in this band, one electron is missing from the valence bond below it. The vacant

FERMI LEVELS

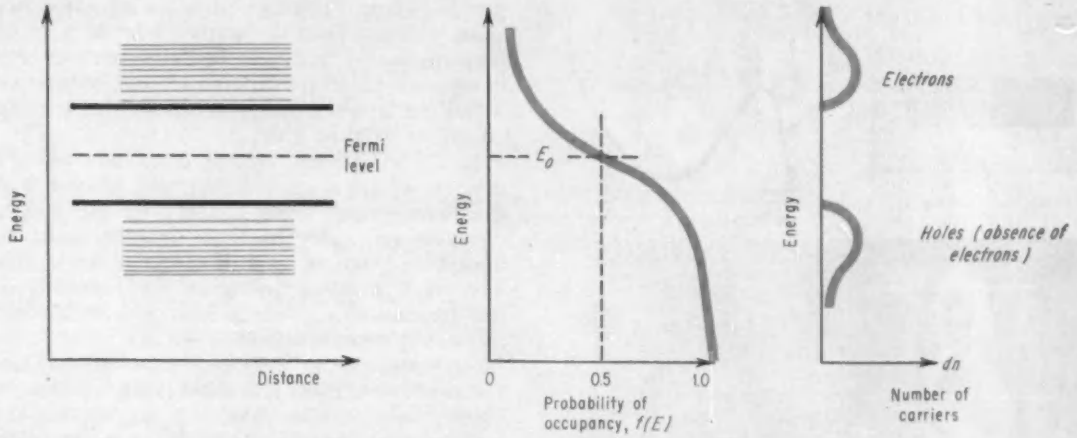


FIG. 6. Energy level diagrams show the physical meaning of the Fermi level. At the Fermi energy, probability that an electron will occupy a level is one half.

spot is called a hole and acts as a positive charge: it is mobile and takes part in the conduction process. Current flow then consists of the movement of both electrons and holes.

Doping

Intrinsic semiconductors are of limited interest because the number of charge carriers depends so strongly on temperature. Resistivity varies by a factor of two for every 10 deg K change in temperature. And, in many respects, it would be more convenient if the semiconductor has only one type of carrier instead of the two types in the intrinsic material.

Doping, the addition of precise amounts of impurities, can produce semiconductors in which current is carried predominantly by holes, P-type

WHAT HAPPENS AT A PN JUNCTION

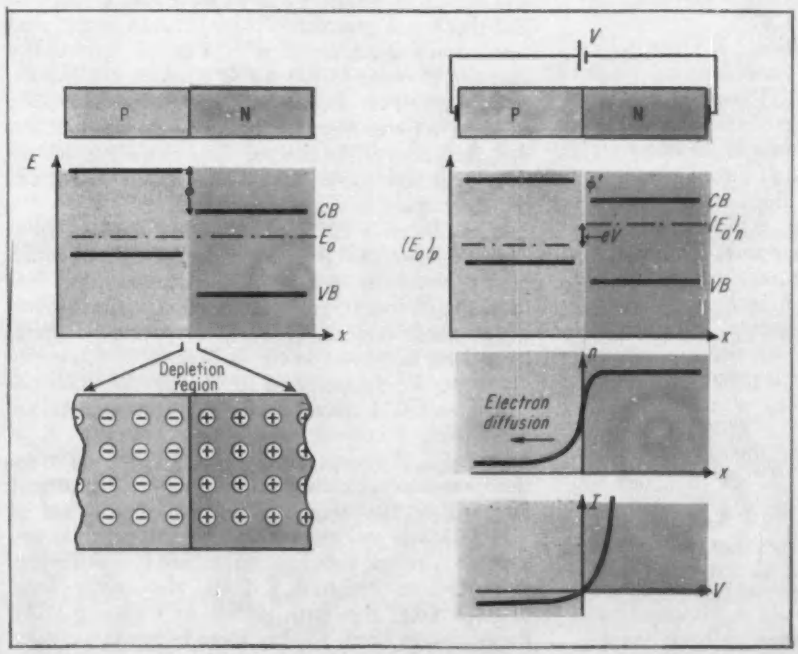


FIG. 7. Before a voltage is applied the Fermi levels are equal in the P and the N material. Application of the voltage across the junction causes a step in Fermi level so electrons diffuse from the N material to the P side. Curves indicate what happens to number of electrons and current.

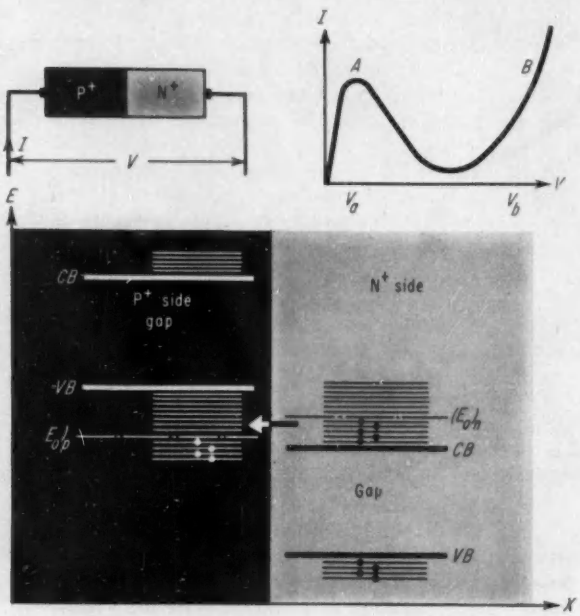


FIG. 8. Heavy doping of PN junction causes an energy level diagram like this. At low voltage V_a, some electrons in filled states in the N material move sideways to empty levels in the P material, supplying the tunneling current at A. As voltage increases, energy levels rise until they parallel the gap and tunneling ceases.

material, or by electrons, N-type material. Doping also increases the number of carriers available, lowers the resistivity, and stabilizes it.

If one part per million of arsenic is added to germanium, for example, 4×10^{16} arsenic atoms (called donor atoms) per cc are added. The result is N-type material. Each atom adds one conduction electron because arsenic has five electrons in its outer shell rather than the four needed to fit into a germanium lattice. The extra electron is free to move, cutting the resistivity to 0.04 ohm-cm, compared to a resistivity of 47 ohm-cm for germanium at 300 deg K.

Doping with a material that has three electrons in the valence shell—a substance such as gallium or boron—produces a P semiconductor. If an atom of this substance is added to the four electron lattice of germanium, an electron is missing, leaving a hole.

After doping, the resistivity is unaffected by increases in temperature over a wide range—until the number of electrons excited sufficiently to jump the forbidden energy gap of 0.7 eV is about the same as the number added by doping.

Injection at junctions

Many devices have been made by joining different types of semiconductor material. A PN junction is normally a single crystal of semiconductor material in which part of the crystal is P-type material and part is N-type. The two parts are separated by a space charge. Such a junction shows rectifying properties and a diode can be built with two layers of dissimilar material. A transistor can be produced with three layers of dissimilar semiconductor material, either NPN or PNP.

In a PN junction, current flows only when an external voltage is applied. Without a bias voltage, the Fermi energy levels equalize on each side as electrons and holes cross the junction until the immediate junction region is devoid of free carriers. The only charges remaining are the ionized immobile impurity atoms which form a depletion layer and an electrostatic voltage barrier ϕ.

Application of an external voltage bias produces a step in Fermi levels across the junction. The step lowers the electrostatic barrier to ϕ', allowing electrons to pass from the N to the P region of the junction where they diffuse as minority carriers away from the junction.

Carrying a current across the junction this way is called injection. Injected electrons combine with holes in the P material within a few diffusion lengths. In the same way, holes are injected into the N material and also carry current across the junction. The current that can be carried depends on the bias voltage and is given by the expression:

$$I = I_s [(\exp qV/KT) - 1]$$

where I_s = the small saturation current for reverse bias.

Tunneling

If an electron has an energy E, you would expect that it would not be able to travel through a potential barrier of height V_o if V_o were greater than E. But this is not completely true. Because of the electron's wave character there is a certain probability that the electron will "tunnel" through the barrier.

This quantum mechanical tunneling takes place inherently faster than the minority carrier injection described above. Because of this, tunneling devices operate at high speed; tunnel diodes have been built for kilomegacycle per sec operation.

Normally in a PN junction, the transition from P to N material takes place over 10^{-4} in., which means many thousands of lattice spacings. For tunneling to occur, the transition has to take place within about one hundred lattice spacings. Doping levels have to be very heavy, as high as 10^{19} impurity atoms per cc, compared to 10^{15} to 10^{17} for injection.

The so-called tunnel diode has a current-voltage curve with a current peak at low voltages (A in Figure 8). The peak cannot be explained by injection processes which are responsible for the current flow at B of the curve.

Here is one way to explain what happens. When a small forward voltage bias, about 100 millivolts, is applied to the tunnel diode, the energy band diagram takes the form shown in Figure 8. The Fermi energy level, E_o, has moved into the valence

PHOTO PHENOMENA

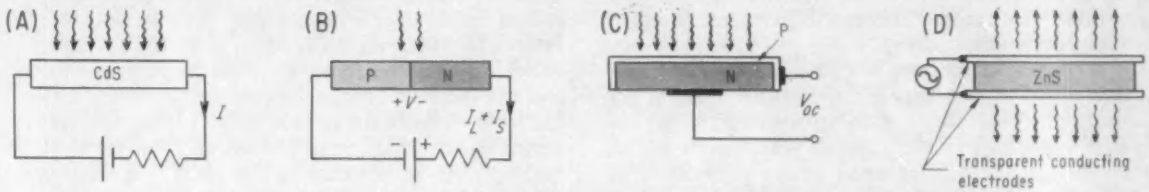


FIG. 9. Four types of solid state photodevices: (A) photoconductive; (B) photoelectric junction; (C) photovoltaic junction; (D) electroluminescent panel.

band of the P-type material and into the conduction band of the N-type material because of the heavy doping. The displacement between the levels $(E_f)_p$ and $(E_o)_n$ is eV, where V is the bias voltage. The diagram also shows that energy states above the Fermi energy levels are empty, while those below are filled. Because of the difference in Fermi levels, some of the electrons in the N conduction band are equal in energy to unfilled states in the P valence band. The wave nature of electrons allows a small fraction to cross into the empty P states without having to jump any energy barrier. This tunneling can take place only if the transition region is thin enough. Tunneling electrons are responsible for the current in region A of the curve in Figure 8.

As the bias voltage increases, the Fermi energy level in the N material moves up, until the electrons in the conduction band of N are in line with the energy gap in the P material where there are no allowed energy states. The probability of tunneling becomes zero, and the current drops to the low shown. As the voltage increases still further, the conventional injection process starts.

The Hall effect

If a bar of semiconductor material (or conductor material) is placed in a magnetic field perpendicular to its axis, and if a current flows axially through the bar, an electric field develops perpendicular to both the magnetic field and the current. This phenomenon is known as the Hall effect. The electric field deflects the current carriers, bending their direction of movement, the same way the electron beam is aimed in a cathode ray tube. The Hall effect can measure the carrier density in a sample and determine whether the current is carried by electrons or holes. In such a measurement a key quantity is the Hall coefficient, given by the equation

$$R = \frac{F}{JB}$$

where R is the Hall coefficient, F is the electric field, J is the current density, and B is the magnetic field strength.

The Hall coefficient for semiconductors is also

$$R = \frac{3\pi}{8} \cdot \frac{1}{qn}$$

where q is the charge on the electron and n is the carrier concentration.

The electric field that develops sets up a potential difference, the Hall voltage, which is given by

$$V = \frac{RIH}{t} 10^{-8} \sin \theta$$

where R is the Hall constant of the material, cc/coulomb; I is the input current, amps; H is the magnetic field strength, gauss; t is the thickness, cm; and θ is the angle between the current and the field.

Originally the Hall effect was the physicists' tool for quality control of semiconductor materials. Now the effect is being put to work. For example, if a Hall generator (a piece of semiconductor material) has a constant current flowing through it and is placed in a nonuniform magnetic field, the Hall voltage is a measure of the generator's position. Thus accurate measurement of displacement is possible. (For a detailed description of how the Hall effect is used for measurement see p. 138.)

If the Hall voltage is shorted out—either externally or by specimen shape—current flows across the specimen as well as axially. This current, at right angles to the input current, generates a Hall voltage of its own, one that opposes the original flow of current. The net effect is to increase the resistance of the material in the presence of the magnetic field. This is called the *magnetoresistance* effect.

PHOTOELECTRIC PHENOMENA AND ELECTROLUMINESCENCE

Four useful solid state phenomena are associated with radiant energy illustrated in Figure 9. They are (a) photoconductivity in semiconductors, (b) photo effects in junctions, (c) photovoltaic functions, and (d) electroluminescence. For a detailed description of how solid state devices are used in radiation detection and measurement see p. 142.

Photoconductors

When light impinges on a film of semiconductor material, an electron in the valence energy band may gain enough energy from a collision with a photon to jump the energy gap to the conduction band. This creates both an electron and a hole (an electron-hole pair), increasing the conductivity of the material. Because the lifetime of a carrier pair is only a few microsec, the magnitude of photoconductivity is limited for a given light density. One way to increase the lifetime is to trap holes at im-

purity centers in the crystal, thus delaying recombination. This increases photosensitivity but decreases speed of response.

A photon whose energy is smaller than the energy gap tends to pass through the crystal without absorption. That means that, to respond to the low energy photons in the infrared spectrum, a photoconductor has to have small energy gaps. In addition, the conductor should operate at low temperature to reduce the number of carriers made available by thermal agitation.

At liquid nitrogen temperature, lead sulfide in oxidized polycrystalline form is sensitive to low frequency (that is, low energy) radiation whose wavelength is as long as four microns; lead telluride is even more sensitive, and will detect radiation whose wavelength is six microns; and lead selenide can detect radiation out to 8 microns.

Cadmium sulfide is an excellent detector for short wavelength radiation such as X-rays, fast electrons and alpha particles, and ultraviolet because its energy gap is large, 2.4 eV. It can operate at 100 deg C without serious loss of sensitivity.

Photoeffects in PN junctions

When a light photon strikes a PN junction it also will generate a hole-electron pair. If the pair is created in the transition range, the electron will flow to the N region and the hole to the P region so that a full electron charge flows through the external circuit. If the pair is generated deep in the N region, however, the hole must first diffuse to the transition area before it can be collected. On its way to the junction it has a good chance of recombining with an electron. Similarly, if the pair is generated deep in the P region, the electron has a good probability of recombining before it can be collected. The total photocurrent that can be generated by a junction is expressed by this equation:

$$I_L = eN_o(w + L_p + L_n)$$

where I_L = photocurrent
e = charge of the electron
N_o = number of hole-electron pairs generated per meter length per sec
w = width of transition zone
L_p = average distance over which holes will be collected
L_n = average distance over which electrons will be collected

A PN junction can be used two ways. If the junction is biased in the back direction (the P side connected to the negative pole of a battery, for example) the whole current I_L is collected. The junction diode is then used as a photoelectric cell or photodiode. The diode is a current generator with high internal resistance. If the junction is left open, however, the light develops a voltage across the open-circuited terminals. The result is known as the photovoltaic effect, and the device is called a photovoltaic cell.

Design of a device to take advantage of the photoeffect at the junction depends on the application; two major approaches are used. In one type, the incident light is parallel to the junction so the response occurs over a limited area close to the junction. The effect can then be used to track a light beam. In the other type, a surface junction is used and the incident light is directed perpendicularly to the surface. Since the surface on which the light impinges is very thin, every photon of light absorbed can generate an electron in the circuit. Solar batteries rely on this technique; they are frequently made by diffusing a thin layer of boron into silicon.

Electroluminescence

Luminescence means that a crystal emits light under the influence of energy imparted to it. If a strong alternating electric current excites the emission of light, the phenomenon is called electroluminescence.

What happens simply is that the electric field of the current induces an electron in one energy level to jump an energy gap to another. On its return to the lower energy state, the electron emits radiation in the visible spectrum. The frequency of the emitted radiation is given by the expression

$$h\nu = E_2 - E_1$$

where h is Planck's constant, ν is frequency of emitted light, E_2 is energy at the level before emission, and E_1 is energy at the level after emission.

Actually what happens is very much more complicated. Special impurities in the crystal lattice called activator atoms are required, and the electron energy transition involves luminescent trapping centers which are activated by a field emission tunneling of electrons through the barrier region of the phosphor surface. Finally, the radiation emitted is varied slightly by the vibration of the lattice.

Light intensity generated by electroluminescence depends on the amplitude of the applied voltage at a given frequency. The relation is:

$$L = L_o\left(\exp - \frac{b}{V^{1/2}}\right)$$

where L = light intensity,
L_o = constant proportional to frequency
b = a constant for the specimen
V = applied voltage.

The main application of electroluminescence to date has been in information and data display. However a panel of electroluminescent material in contact with a photoconductive layer forms a light amplifier which can give an increased light output. For a report on progress in electroluminescent materials, and a survey of available devices, see p. 180.

FERROMAGNETISM

In a ferromagnetic material, a magnetization remains after a magnetic field has been applied and then removed. This phenomenon results from the spontaneous magnetization of small regions of the crystal called "domains". Hysteresis is a different aspect of the same spontaneous effect.

Spontaneous magnetization can be traced to an

exchange energy which develops as the result of a change in electrostatic energy brought about by a difference in electron spins. Since two electrons will stay farther apart if they have the same spin than if they have different spins, their electrostatic repulsion energy is smaller.

In iron, for example, in the unmagnetized state the lowest energy band should have three electrons per atom in each of two partial bands—each partial band would be filled with five electrons. The electrons in each partial have the same spin.

But iron is never found in this state. There is a configuration that has a lower energy level: five electrons with the same spin in one partial band and one electron with the opposite spin in the second. All the electrons with the same spin have caused a much lower electrostatic repulsion . . erg . .—the energy band is lowered by the exchange energy. At the same time, an opposite effect occurs. The Fermi energy level is raised since the states occupied at the top of the filled band have larger kinetic energies than the states made vacant near the middle of the other band. Since the effect of exchange energy is greater than the increase in Fermi energy, the stable observed condition is the magnetized state.

Thus a ferromagnetic material can be defined as any solid in which the lowering of the energy by the exchange interaction is greater than the increase in Fermi energy. This condition occurs for a few elements such as iron, nickel, and cobalt.

For the exchange interaction to cause magnetic moments of the electrons to align in magnetism, the separation of atoms is critical. If the spacing is too small, the Fermi energy increases more than the exchange energy. If the spacing is too large, the exchange interaction becomes too weak to force alignment. Based on this criterion, an alloy such as copper-manganese should be ferromagnetic if the atomic separation is in the order of that of iron. Experiment confirms this.

Since the energy difference between the magnetized and unmagnetized states is only a few tenths of an electron volt, increasing the temperature ultimately destroys spontaneous magnetism. At a point called the Curie temperature spontaneous magnetism disappears. Typical Curie temperatures: iron, 1,043 deg K; cobalt, 1,400 deg K; nickel, 631 deg K.

PIEZOELECTRICS AND FERROELECTRICS

In an electric field, a ferroelectric crystal shows an electric dipole moment in the same way a ferromagnetic material shows a magnetic dipole when in a magnetic field. Such crystals can be thought of as the electrical analogs of ferromagnetic materials. The prefix "ferro" in this case has no significance since the materials are not associated with iron. Some typical ferroelectric crystals are barium titanate, rochelle salts, and sodium titanate.

The dipole effect is the result of the separation of negative and positive charge either by a slight displacement of ions in the crystal or by relative movement of the atom nucleus and its electrons. A piezoelectric crystal undergoes a dimensional change as well as polarization when subjected to an electric field. Conversely, when a piezoelectric crystal is squeezed, bent or twisted, it generates an electric voltage, the result of moving electric charge.

To be piezoelectric, a crystal has to have a lattice with no center of symmetry. In the two dimensional lattice of Figure 10, the dotted circle encloses a basic unit of one positive ion and three negative ions. If this is compressed along the x axis, the negative ions (numbered two and three) are squeezed slightly together, and the circle acquires polarization in the y direction.

A ferroelectric crystal will show piezoelectric properties, but the converse is not necessarily true. When the piezoelectric material exhibits hysteresis of the polarization charge, even to the extent of spontaneous polarization or retention of the last applied direction of polarization, it is a ferroelectric. Barium titanate is the best known ferroelectric; it polarizes spontaneously when cooled through the Curie temperature, 120 deg C. What happens is the titanium ion achieves a lower energy by moving relative to the oxygen ions. As spontaneous polarization occurs, the lattice changes from cubic to tetragonal.

Polarization is of the order of 10^{-5} coulombs/sq cm and the coercive field may be about 10^{3} volt/cm. When an electric field is applied to change the direction of polarization, the reversal is a domain proc-

PIEZOELECTRIC EFFECT

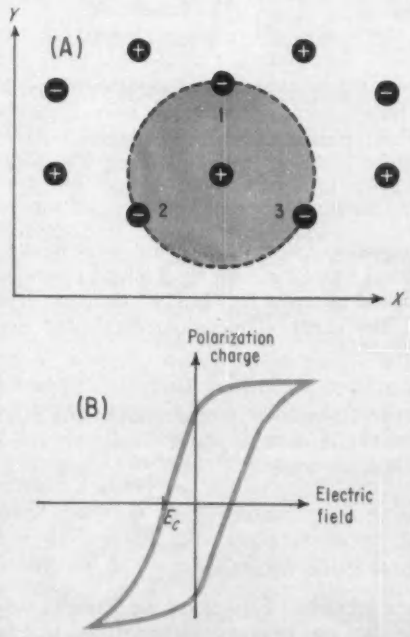


FIG. 10. Basic unit of a two dimensional lattice enclosing one positive and three negative ions. When the lattice is compressed in the x direction, negative ions move closer, and polarization occurs in the y direction. Curve below plots charge versus electric field and closely resembles typical magnetic hysteresis curve.

ess. A domain is an area within the crystal in which the molecular structure is polarized and the domain structure is very complex. When an electric field is applied, the walls of the domains move.

Memory plates of a single crystal of barium titanate have been made with switching times of less than a microsec. Dielectric amplifiers and modulators of ferroelectric materials have also been proposed. However, use of ferroelectrics has been limited by detrimental temperature effects and losses.

Not so limited has been the application of piezoelectric crystals. They are used as "motors" in sound transducers, and as "generators" in strain gages. For more information on how piezoelectrics are applied for measurement see p 134.

THERMOELECTRIC PHENOMENA

Three thermoelectric phenomena are of interest to engineers. They are the Seebeck, Peltier, and Thomson effects. Information on their application is included in the articles on pages 173 and 178.

In the Seebeck effect, a voltage is generated by joining two dissimilar metals in a closed circuit and maintaining the two junctions at different temperatures. Thermocouples that measure temperatures are based on this phenomenon. Thermoelectric power sources also depend on this effect.

In the Peltier effect, which may be regarded as an inverse Seebeck effect, an external voltage is applied to two dissimilar metals that are joined, and one junction cools while the other heats. If the voltage is reversed, the warm junction cools, and the junction that previously cooled starts to heat. Today, this effect is being used in cooling electronic equipment, in home air conditioners, and in home appliances such as baby bottle warmers and ice makers.

When an electric current is passed through a bar conducting heat, an absorption or generation of heat takes place—depending on the material of the conductor and the direction of current flow. If the electric current in an iron bar, for example, moves from the cool to the hot end, the bar tends to heat; if the current is reversed the bar tends to cool. This is the Thomson effect, which was discovered during a study of the temperature dependance of the Peltier effect.

Thermodynamic concepts

The first and second laws of thermodynamics—the conservation of energy and the production of entropy—fail to explain satisfactorily these three phenomena which involve the flow of heat and current. Introducing some concepts of statistical mechanics helps explain them.

Electric fields and temperature gradients can interact in several ways; the cross effects are termed thermoelectric phenomena. For example, an electric field moves the electrons in a conductor in the direction of the field, with associated flow of energy, and modifies the statistical velocity distribution in that direction. The velocity distribution is also affected by a temperature gradient in the conductor. If any concentration gradients arise they can produce thermal diffusion potentials.

The Onsager Theorem of Thermodynamics, which is based on statistical mechanics, states that "flows", J_1, J_2, J_3 ..., caused by driving forces, X_1, X_2, X_3 ..., may be represented by a general equation:

$$J_i = \sum_{k=i}^{n} L_{ik}X_k \qquad (i = 1,2,...n)$$

The theorem also states the conditions that must be satisfied if the transfer coefficient L_{ik} is to equal L_{ki}.

When these conditions are applied to a problem of simultaneous current, I, and heat flow, J, the equations become

$$I = -L_{11}\frac{\Delta V}{T} - L_{12}\frac{\Delta T}{T^2} \tag{5}$$

$$J = -L_{21}\frac{\Delta V}{T} - L_{22}\frac{\Delta T}{T^2} \tag{6}$$

where $L_{12} = L_{21}$

These coefficients have physical meaning. For example, if ΔT in Equation 5 is zero, the ratio $-L_{11}/T$ must represent electrical conductance. If a temperature gradient is present and the current is zero, the equation predicts a thermoelectric voltage.

$$\Delta V = -\frac{L_{12}}{L_{11}}\frac{\Delta T}{T}$$

This represents the Seebeck effect. The thermoelectric power coefficient, α, is given by

$$\alpha = \frac{\Delta V}{\Delta T} = \frac{-L_{12}}{L_{11}T}$$

If ΔV is eliminated in Equations 5 and 6, the relation for heat flow becomes

$$J = \frac{L_{21}I}{L_{11}} - \frac{(L_{11}L_{22} - L_{12}L_{21})\Delta T}{L_{11}T^2}$$

Then if ΔT is zero and the conventional Fourier heat flow (represented by the second term of the equation) is eliminated, the equation shows a heat flow from junction 1 to junction 2 whose value is:

$$J = \frac{L_{21}}{L_{11}}I$$

This equation implies that the current flow I causes junction 1 to take in heat from a heat reservoir 1 and junction 2 to reject this heat to reservoir 2. This is the Peltier effect. The Peltier coefficient is

$$\pi = \frac{L_{21}}{L_{11}}$$

Since the Onsager reciprocal relation says L_{12} equals L_{21}, the thermoelectric power coefficient and Peltier coefficient are related.

$$\alpha = -\frac{\pi}{T}$$

Physical interpretation

These relations of statistical mechanics yield quantitative, but not physical, information. If a homogenous bar of semiconductor has a temperature

gradient so that end A is at temperature T and end B is at $T + \Delta T$, the temperature difference produces two significant effects:

- The distance of the Fermi level from the conduction band of energy is greater at B than at A since the Fermi expression involves T (Equation 4).
- The electrostatic potential of the conduction energy band becomes more positive at B than at A because the higher temperature redistributes free electrons, creating an electric field condition.

The Peltier effect, for example, can be explained by an examination of the energy changes that occur when a current flows across a PN junction. In such a junction, the energy level diagram might look like that in Figure 11. Each electron injected into the P region from the N side experiences an increase in potential energy equal to $(E_{CP} - E_{CN})$; this represents energy taken from the crystal lattice. After traveling a distance equivalent to the diffusion length, the electron combines with a hole releasing potential energy E_g. The lattice receives a net energy release equivalent to $E_g - (E_{CP} - E_{CN})$.

Other energy is released to the lattice, too. Since a current is flowing, both the electron and the hole have kinetic energy of flow. At combination, the electron and the hole release energy amounting to 2 KT. The Peltier energy released is the sum of the gain in energy by an electron and the kinetic energy of a hole-electron pair. Similarly at the other junction, the same amount of heat is taken from the crystal lattice.

Heavily doped semiconductors have operated as thermoelectric coolers with a cooling effect up to 60 deg C. And in a power generator, thermoelectric effects have produced tens or hundreds of watts, with efficiencies of from eight to 10 percent.

CRYOGENIC PHENOMENA

About twenty metallic elements exhibit complete loss of resistance when cooled to temperatures below certain values in the range of 0.5 to 9 deg K. The phenomenon is called superconductance. Currents of several amps induced into superconductive rings persist for several years without any diminution in magnitude of current.

The application of a magnetic field lowers the critical temperature at which superconductivity occurs. As a result, raising or lowering the intensity of a magnetic field can control the resistance of the material by causing it to shift from the superconductive state and back again. This principle has potential application in both memory and logic circuitry (see pages 150-159).

What happens in superconductivity is not completely understood. One explanation can be found in Reference 5. In a simplified form, the explanation depends on an assumption that each electron near the Fermi level becomes correlated in wave function to an electron of opposite spin. A lattice vibration causes this interaction in the superconductive state. Once such a pattern is established, the normal mechanism of scattering, which is responsible for resistance in conventional conductors, cannot scatter the pair since it doesn't have sufficient energy. Thus correlated electrons carry the whole current, short out the normal state electrons that may be present, and severely inhibit the dissipative processes that depend on single electron processes.

PELTIER EFFECT

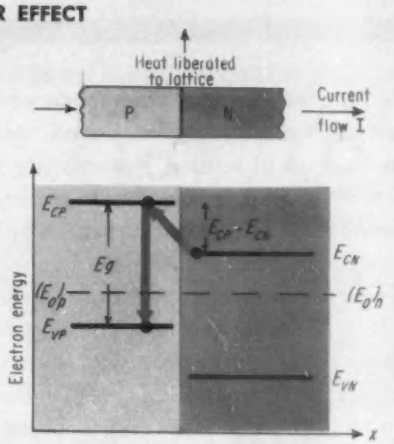


FIG. 11. Energy level diagram for a PN junction helps explain how energy is released in Peltier effect. Electron moves from E_{CN} to E_{CP} to E_{VP}.

Another explanation, proposed by Barden-Cooper-Schrieffer, hypothesizes an energy gap in the band structure. Some substantiation of this approach comes from the tunneling of electrons between superconducting metals, an effect that has been observed only recently.

Another low temperature phenomenon, unrelated to superconductivity, is the impact ionization effect. At a temperature of 4 deg K in an electric field, the few conduction electrons that are normally present acquire energies sufficient to ionize the impurities, thereby creating more carriers. A nondestructive breakdown takes place, as in a gas discharge tube. The application of this small electric field can cause a rise in current of many orders of magnitude —for example, from 10^{-8} to 10^{-3} amp.

Memory plates and bistable switching structures are examples of devices based on this phenomenon. They have been called Cryosar and Cryosistor.

REFERENCES

For the engineer with a deeper interest in solid state phenomena, the following references are suggested for further reading.

1. *MODERN PHYSICS*, R. L. Sproull, John Wiley and Sons, New York, 1956.
2. *SOLID STATE PHYSICAL ELECTRONICS*, A. Van der Ziel, Prentice Hall, Englewood Cliffs, N. J., 1957.
3. *THE SOLID STATE FOR ENGINEERS*, M. J. Sinnott, John Wiley and Sons, New York, 1958.
4. *ELECTRICAL ENGINEERING MATERIALS*, A. J. Dekker, Prentice Hall, Englewood Cliffs, N. J., 1959.
5. *THEORY OF SUPERCONDUCTIVITY*, L. N. Cooper, American Journal of Physics, February 1960, pp. 91-101.

Measurement experts have found new and useful ways to exploit solid state phenomena. As a result, four distinct classes of sensing elements are now practical and available. This article covers strain gages and transducers based on piezoresistive and piezoelectric principles, and tabulates some strain gage elements, accelerometers, pressure gages, and load cells. The second article examines the Hall effect and a wide range of resulting sensing devices. The third surveys solid state sensors of infared, visible, and nuclear radiation, and the fourth considers semiconductor thermometers—mainly germanium probes for cryogenic temperatures.



Piezoelectric and Piezoresistive Strain Gages

E. JONES, Kulite-Bytrex Corp.

Two different solid state phenomena—piezoelectricity and piezoresistivity—are useful for strain and strain-equivalent measurements. Piezoelectricity, a property of asymmetrical crystals, is the appearance of a charge or potential resulting from a strain-induced change of state of bound electrons. Measurement of voltage indicates strain value. Piezoresistivity, a property of symmetrical crystals, is a change in resistance resulting from a strain-induced change in the state of mobile electrons. Here, measurement of resistance indicates strain value.

For strain gage elements, the most useful piezoelectric materials are quartz, barium titanate, and other metallic titanates, zirconates, and crystallographically similar compounds. The most useful piezoresistive materials are silicon, germanium, and gallium arsenide.

Since both phenomena depend on electron activity within the crystal lattice and since temperature is also associated with electron activity, the phenomena are temperature dependent. This is a considerable drawback when such solid state devices are used for measurement, and a good deal of effort has gone into methods of lessening temperature dependency, either internally, by crystal choice or doping, or externally by compensating. For the most part these methods have been more successful with piezoresistive than piezoelectric materials.

Strain gage elements

Piezoresistive strain gages use techniques and auxiliary instruments long associated with the similar and familiar wire strain gages. The gage factor of wire strain gages ranges from 2 to 6. Semiconductor strain gage elements, however, have gage factors ranging from 100 to 200, and with proper crystal doping both positive and negative gage factors can be obtained. Table I lists representative semiconductor strain gages, all of the peizoresistive type, and the title photo shows one piezoresistive strain gage element with handling jig.

Little has been done toward using piezoelectricity as a strain gage, mainly because of the difficulty of maintaining a steady output from the static input usually associated with strain measurements. The difficulty arises because, with zero or low frequency changes in strain, the charge generated by the crystal (basically a capacitance) will leak off through the measuring instrument resistance.

While most strain gage elements are used for stress analysis in the laboratory, for many control applications—where it is impractical to fit in a complete transducer—the strain gage element (or more often a complete strain gage bridge) is cemented to the structure at a point where strain magnitude is a true measure of the quantity to be controlled. Semiconductor strain gages have been used to control rolling mill loads and to weigh storage tank contents.

For best accuracy, the basic piezoresistive strain gage element and its measuring circuit should be compensated and calibrated under controlled conditions after installation, which is an almost impossible task in the field. Instead, transducers—in which all compensations have been made under laboratory conditions, all characteristics have been determined, and (in some cases) output has been set to a standard—ease the field installation problem and make the units interchangeable.

Strain gage transducers

Besides the measurement of strain per se, strain gage elements are employed in such transducers as accelerometers, load cells, and pressure cells. Theoretically, either the piezoresistive or the piezoelectric strain element may be used in these transducers, but practical requirements may indicate preference for one or the other.

The piezoelectric transducer is self-generating. Therefore, only two output leads are needed. The output is expressed in millivolts or micromicrocoulombs per unit of input variable. The charge sensitivity and capacitance of a piezoelectric crystal increase with increasing temperature; resistance decreases. These characteristics can be used to compensate the transducer, but the capacitance and temperature coefficient of capacitance of the cable and amplifier must also be taken into account. Furthermore, the crystal, cable, and amplifier resistances should be very high for best low-frequency response; for instance, the instrument input impedance should be between 100 and 10,000 megohms. Because of these and similar considerations manufacturers prefer to supply the transducer, cable, and amplifier as a package to provide best over-all operation.

The temperature coefficient of present piezoresistive elements is so large that, unless compensated, a transducer undergoing large ambient temperature fluctuations could provide nearly as much spurious signal due to temperature as true signal due to strain. A Wheatstone bridge, which provides good compensation and a convenient means of measuring the resistance change, is almost universally used with piezoresistive gages and transducers, just as for wire strain gages and transducers. Ideally, four gage elements, two in tension and two in compression, are connected as a bridge such that the resistance change due to temperature cancels and that due to strain adds to the measured unbalance. A second order of compensation can be obtained with temperature-sensitive resistances mounted in the transducer and appropriately connected to the Wheatstone bridge.

The piezoresistive bridge-transducer requires an external voltage source to make a resistance measurement so output is proportional to both measured variable and exciting voltage. Such transducers are therefore rated in millivolts output per volt input for full range of input variable.

What's available

Piezoelectric transducers, particularly a wide variety of accelerometers, have been available for many

PIEZOELECTRIC TRANSDUCERS

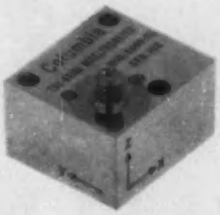


FIG. 1. *Columbia piezoelectric accelerometer, 1⅛ x 1⅝ in.*



FIG. 2. *Endevco piezoelectric accelerometer, 9/16 in. hex.*

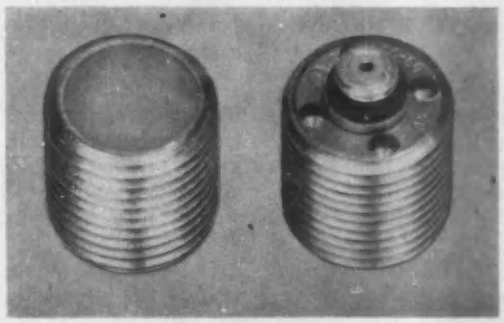


FIG. 3. *Atlantic Research piezoelectric pressure cell, ½-in. thread.*

TABLE I—Semiconductor Strain Gages

Manufacturer	Model	Resistance, ohms	Gage factor	Eff. gage length, in.
Century	711	120	+130	0.35
Micro-Systems	MS301-120	120	+110	0.05
"	MS202-120	120	−100	0.16
"	MS302-350	350	+120	0.16
"	MS305-1000	1,000	+120	0.5
"	MS235-1000	1,000	−100	0.5
Kulite-Bytrex	DB-107	120	+140	0.1
"	DBN-102	120	−100	0.25
"	DB-105	1,000	+170	0.25
"	DB-108	10,000	+180	0.25
"	MP-102-6	120	+220 (effective)	0.25

years. Such transducers, a few of which are shown in Figures 1, 2, and 3, are small, simply constructed, and generally use direct stress to preserve the ultimate in stiffness so necessary for high-frequency response. Piezoresistive transducers are more recent, but even so, numerous devices are available. Again, only a few are shown, Figures 4, 5, and 6. These generally are large, have rugged covers and electrical connections, and often use bending stresses and mechanical linkages to multiply forces and thus extend the measuring range. An exception to the usual large piezoresistive transducer is the miniature Kulite-Bytrex pressure cell, Figure 7.

Table II lists semiconductor accelerometers (all except one being piezoelectric) indicating the wide range of characteristics available in such transducers. Table III lists pressure transducers and Table IV load transducers of both the piezoelectric and piezoresistive types to suit a variety of dynamic and static applications. All tables are partial listings.

Since piezoelectric transducers are used to a small fraction of their capacity, they are not usually made in as many ranges as are piezoresistive transducers. No attempt has been made to include sound and shock pressure transducers, which are available as piezoelectric devices in many shapes and sizes.

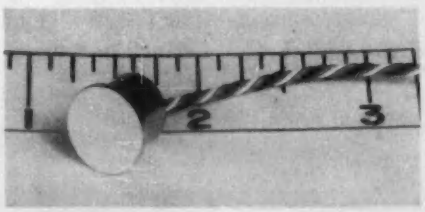


FIG. 7. *Kulite-Bytrex miniature piezoresistive pressure cell.*

PIEZORESISTIVE TRANSDUCERS

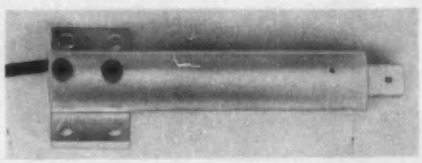


FIG. 4. *Kulite-Bytrex piezoresistive load cell for force and deflection measurement.*



FIG. 5. *Fairchild piezoresistive pressure transducer, ruggedized.*



FIG. 6. *Century piezoresistive pressure transducer.*

TABLE II—Semiconductor Accelerometers

Manufacturer	Model	Range, g	Natural freq., kc	Max. temp., deg. F	Output, mv/g
PIEZOELECTRIC					
Columbia	408	10,000	55	300	100
"	606HT	40,000	135	500	2.5
"	510TX	1,000	100	300	20 (triaxial)
"	50X2	75	15	165	2,000 (includes amplifier)
Massa	M 198	500	18	160	125
Endevco	2219	20	12	230	350
"	2215	2,000	30	185	8
"	2242	1,000	40	500	10
"	2223C	2,000	25	350	10 (triaxial)
Clevite	2E1	1,000	150	400	1.5
"	20CW1	1,000	30	400	20
PIEZORESISTIVE					
Kulite-Bytrex	AP-4	4	0.3	300	500

TABLE III—Semiconductor Pressure Cells

Manufacturer	Model	Range, psi	Other ranges	Natural freq., kc	Max. temp., deg. F	Output
PIEZOELECTRIC						
Kistler	601	5,000	to 100,000	100	500	0.5 μμC/psi
"	401	3,000		50	400	5 μμC/psi
Endevco	2501-2000	2,000	500	50	230	12 μμC/psi
Atlantic Research	LC 60	100			160	300 μμC/psi
PIEZORESISTIVE						
Century	750	100	25-10,000	1	250	142 mv/v/F.S. (28 v max.)
Dynisco	PT500	500	15-1,000	2	300	200 mv/v/F.S. (25 v max.)
Fairchild	3 SG*	2,000	100-10,000	60	250	10 mv/v/F.S. (28 v max.)
Statham	PG313-5M-70	5,000				200 mv/v/F.S.
Kulite-Bytrex	HF-100*	100	50-500	75	300	40 mv/v/F.S. (3 v max.)

*Available with amplification for 5 volt output.

TABLE IV—Semiconductor Load Cells

Manufacturer	Model	Range, lbs	Other ranges	Stiffness, lb/in.	Max. temp., deg. F	Output
PIEZOELECTRIC						
Kistler	510	5,000		.....	500	.....
Endevco	2104	5,000	100 up	14×10^6	200	30 mv/lb
PIEZORESISTIVE						
Kulite-Bytrex	SC500	500	200-2,000	0.17×10^6	150	70 mv/v/F.S. (40 v max.)
"	BC-10	10	10 gr-100 lb	Very low	150	70 mv/v/F.S. (40 v max.)

Hall Effect Transducers

CHARLES WOOD
Kearfott Div.
General Precision, Inc.



Hall effect generators and transducers measure magnetic field strength, current, power, and displacement (plus variables convertible to these). Here is how they work and who makes them.

The small object shown above is a Hall effect generator. When one of these devices carrying a current is placed in a magnetic field, Figure 1, it produces a voltage proportional to the product of current and field strength. This relationship can be made linear within 0.5 percent, and if the control current is held constant, the output varies linearly with field strength, Figure 2. Numerous Hall generators are available, some giving as much as 3.5 volts output in a 10 kilogauss field. The response time of these devices is fast—around 10^{-14} sec—they require no surface protection for indoor environments, and mechanical vibration does not affect their properties unless it is severe enough to break the crystal.

What makes a good Hall generator?

Because power dissipation is what limits control current and hence the Hall output of a particular material, it is helpful to express the open circuit Hall voltage, V, in terms of power dissipation and magnetic field strength.

$$V = 10^{-8}\left(\frac{\mu P w R}{lt}\right)^{1/2} H \qquad (1)$$

where P is the dissipation in watts; H is the magnetic field intensity in gauss; w, l, and t are the width, length, and thickness of the element in cm; R is the Hall constant of the material in cu cm/coulomb; and μ is the mobility of the material in sq cm/volt-sec. (Mobility is the ratio of the velocity of charge carriers in a solid to the electric field intensity responsible for their motion.)

The choice of materials for Hall generators is essentially limited to semiconductors. Conductors have too small a Hall constant, and the high resistance of insulators reduces conversion efficiency. To minimize the temperature dependence of n, the charge carrier concentration, the material should be

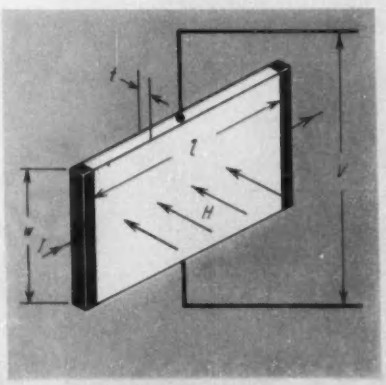


FIG. 1. Hall voltage V varies with control current I and applied field H.

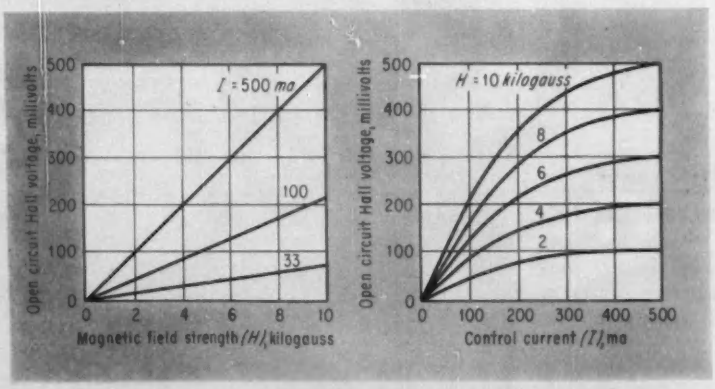


FIG. 2. Output characteristics of Ohio Semiconductors HS-51 indium antimonide Halltron.

extrinsic over the whole temperature range of interest. Because R is proportional to $1/n$, V varies as $(\mu/n)^{\frac{1}{2}}$. The optimum value of n is the smallest that keeps the material extrinsic at the upper end of the temperature range. Materials with a large energy gap are desirable because they maintain extrinsic conductivity with smaller values of n.

The efficiency of a Hall generator connected to a matched load (usually on the order of an ohm) is given by

$$\frac{\text{watts output}}{\text{watts input}} = 2.5 \times 10^{-17}\ \mu^2 H^2 \qquad (2)$$

Allowing for the increase in internal resistance in strong fields (the resistance at 10,000 gauss may be 1.5 times the zero field resistance), it has been shown theoretically that with a single pair of Hall contacts the efficiency cannot exceed 17 percent. Efficiency (and linearity) can be improved by using Hall elements with multiple pairs of input and output contacts to reduce disturbance of the electric field in the element. One indium antimonide Hall generator with six pairs of current contacts and six pairs of Hall contacts had a power conversion efficiency of 50 percent at 10 kilogauss. Materials with high mobility are the best choice.

Where weak magnetic fields are involved, signal-to-noise ratio is the important criterion. The noise in semiconductor filaments is difficult to predict, but from practice, it appears that indium antimonide is to be preferred.

For some measuring applications, linearity is more important than maximum output, and the load connected to the Hall terminals is usually neither high impedance nor matched. In practice, the open circuit Hall voltage increases with field strength in a nonlinear manner. But because of magnetoresistance, the internal resistance of the generator also increases, and this provides a means for linearity compensation. With the proper value of load resistance, the Hall output current drops the excess Hall voltage across the internal resistance, and the correct voltage (approximately) appears at the output.

Temperature characteristics

Figure 3 shows how the Hall constants of three high mobility (InSb, 77,000; InAs, 27,000; and InAsP, 12,000 cm²/volt-sec) materials decrease with increasing temperature. Temperature effects can sometimes be compensated by a thermistor and zero temperature coefficient resistor in parallel, the combination being in series with the Hall generator. But this method reduces over-all efficiency, and is not always effective since the network may fail to follow temperature variations experienced by the tiny Hall element. It is helpful to maintain a constant voltage across the generator, and a heat sink or thermoelectric cooling can be applied.

Dimensions, contacts, and leads

From Equation 2, the open circuit Hall voltage should vary as $(w/l)^{\frac{1}{2}}$, but for values of w/l greater than 2.7 further increase in V is offset by the shorting effect of the control current electrodes. Since V is proportional to t^{-1}, output can be increased by making the generator thinner, and thin film generators show great promise.

If the Hall contacts are not aligned accurately during fabrication, a small voltage appears across them when control current is flowing and the magnetic field is zero. This voltage can be compensated with bias, or minimized by crystal shaping.

Because the control current is not perfectly uni-

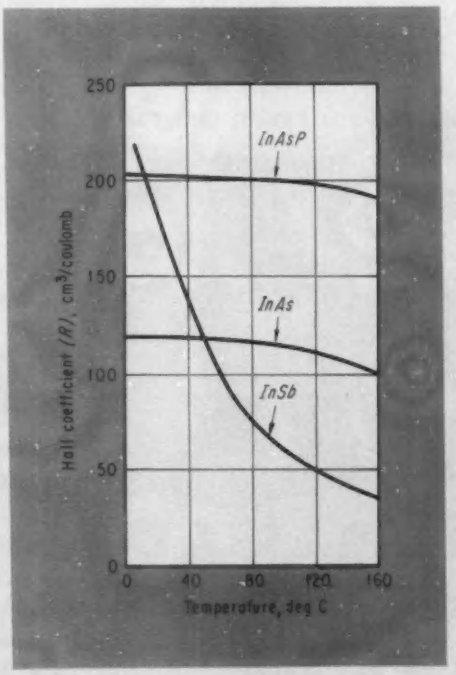
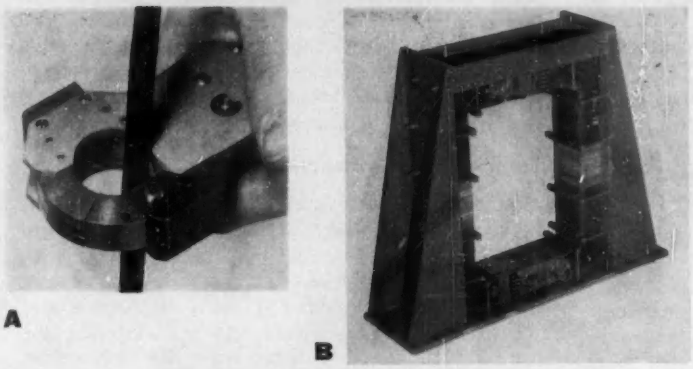


FIG. 3. Indium antimonide (InSb) has a negative temperature coefficient of 15 percent/10 deg C; indium arsenide (InAs), 0.5; and indium arsenide phosphide (InAsP), about 0.25.

FIG. 4. Hall effect gaussmeter by Hallitest Div. of Instruments Systems Corp.



HALL AMMETERS COME IN ALL SIZES



A B

FIG. 5.
Kearfott clip-on ammeter, A, handles 1-100 amp range. Large transducer by Ohio Semiconductors, B, measures to 100,000 amp.

form, power is dissipated unevenly in the crystal, creating thermal gradients that generate Seebeck voltages. This can be minimized by mounting the crystal on a good heat sink.

If the magnetic field applied to the Hall generator is ac, the Hall output leads should be kept in a plane parallel to the flux lines. This prevents an error voltage from being induced.

Measuring magnetic fields

Probably the most straightforward Hall effect application is the measurement of magnetic field strength. The control current is held constant so that the Hall output varies with the normal component of the field. Hall probes are available from Halltest and Ohio Semiconductors with the element oriented along the probe axis for measuring transverse fields or across the end of the probe for measuring axial fields. Some can measure down to 0.001 gauss with amplification and 10 gauss without.

The Hall element's thinness makes it ideally suited for measuring fields in narrow gaps. The probe can be rotated for maximum output to establish field direction, and the polarity of the output indicates field polarity. To measure weak, uniform fields, high permeability rods can be used to concentrate the field on the probe. Complete gaussmeters, Figure 4, are now available.

Field type ammeters

Hall generators can measure ac or dc currents flowing in a conductor by measuring the magnetic field around the conductor. For increased sensitivity, the Hall crystal is inserted into a small gap in a magnetic yoke surrounding the conductor. This principle can be used in small devices for measuring currents down to 1 ma in fixed installations, hand-held clip-on instruments for the 1-100 amp range, Figure 5A, and large transducers for measuring thousands of amperes, Figure 5B.

Hall multipliers

A Hall multiplier is a Hall element packaged with a magnetic circuit. It gives an output proportional to

HOW TO USE HALL MULTIPLIERS

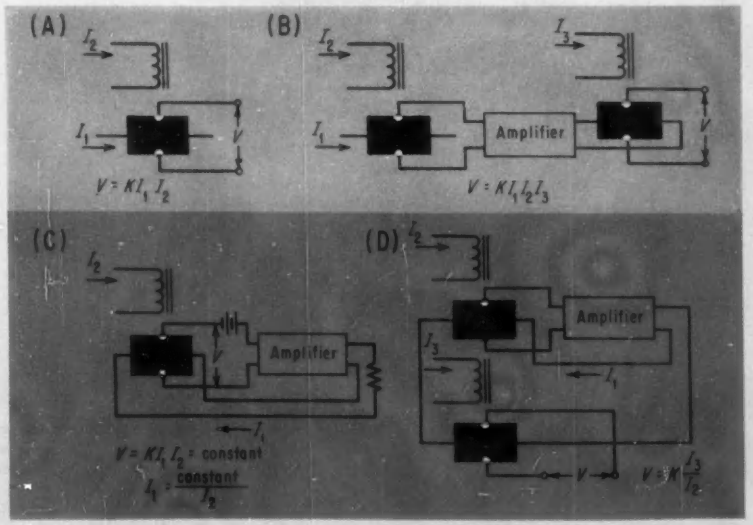


FIG. 6. Hall generator and magnetic circuit can multiply, A and B, invert, C, and divide, D.



FIG. 7. Ohio Semiconductors InAs Hall multiplier has two main windings and auxiliary winding for introducing dither signal or balancing circuit.

the product of two currents: one connected to the crystal itself and one fed to a winding on the magnetic circuit. Figure 6 shows how one such device can multiply two currents or invert an input signal, and how a pair of Hall multipliers can multiply three currents or form a quotient. The magnetic circuits in these units, Figure 7, are generally designed for operation from dc through audio frequencies, and the control current to the Hall crystal can be modulated into the megacycle range. A Hall multiplier can be used as a squaring device by passing the same current through both the crystal and the coil.

Hall effect wattmeters

A Hall multiplier is a natural for measuring electrical power. With the magnetic circuit in series with the load, and a voltage proportional to the load voltage applied to the Hall element, Figure 8A, the Hall output signal contains two components: a dc term proportional to real power, and a double frequency term proportional to apparent power (volt-amp). A dc meter connected to the Hall terminals reads the first term and can be calibrated in watts.

If a 90 deg phase shift is introduced into either the voltage or current circuits, the dc output term is proportional to reactive power, and the device becomes a VAR transducer. One way of getting the phase shift is to make the control current proportional to load current and apply load voltage to the magnetic winding, Figure 8B. Because of the electromagnet's large X_L/R ratio, the field lags the load voltage by close to 90 deg, and additional compensation can make the phase shift exactly 90 deg.

If the load voltage and current signals are converted to dc before multiplying them in the Hall generator, Figure 8C, the phase angle is removed, and only absolute magnitudes are compared. This circuit measures apparent power.

The Westinghouse watt transducer in Figure 9 includes their type 803 InAs Hall generator, a current coil assembly, a potential transformer, and a thermistor temperature compensation circuit. Westinghouse also makes packaged Hall effect wattmeters and VAR meters.

Displacement—Lineal and rotary

A Hall generator placed in a nonuniform magnetic field has an output that is a function of its position. A lineal displacement transducer made by Yokogawa Electrical Works, Inc., has a Ge Hall element and produces a 10-millivolt signal for 2-mm displacement. It has been estimated that Hall effect transducers could detect a displacement of 1 Angstrom (10^{-4} microns) in a gradient of 10 gauss per micron, and high sensitivity is available over a comparatively long traverse distance. Motion-type measuring elements for variables such as temperature, pressure, flow, and level can be coupled to a Hall sensor.

Because the Hall voltage is proportional to the component of magnetic field *normal* to the generator, a Hall element rotated about its control current axis in a lineal magnetic field has an output proportional to the sine or cosine (depending on the reference) of the angle of rotation. By rotating the generator (or the magnet assembly) at different speeds, a wide variety of frequencies can be generated. Because the output voltage is independent of rotational speed, sine waves with frequencies on the order of cycles per hour can be produced easily.

When two Hall generators are mounted on the same shaft but displaced by 90 deg, the unit becomes a resolver. One output is proportional to the sine of the angle of rotation, the other to the cosine. A test resolver with Ge Hall crystals, measured at 400 cps in the Kearfott lab (work supported by BUWEPS), had an accuracy of better than 0.06 percent over the full 360 deg of rotation. This corresponds to a resolution of better than 1 min of arc. This work is currently being extended to the construction of Hall effect synchros.

A HALL EFFECT TRANSDUCER FOR ANY KIND OF POWER

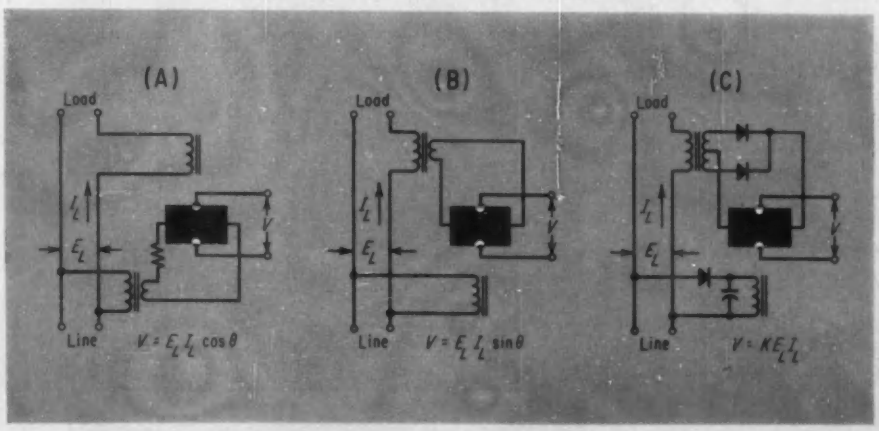
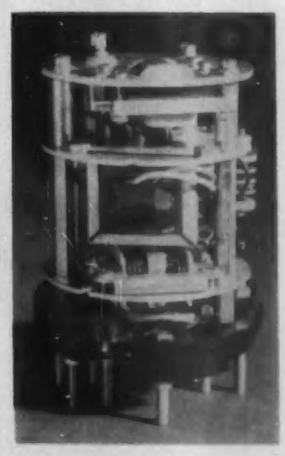


FIG. 8. Circuits for measuring real, A, reactive, B, and apparent, C, power.

FIG. 9. Westinghouse VP-840 watt transducer comes in single, two, and two and one-half element models with high or low (50 ohm) impedance output.

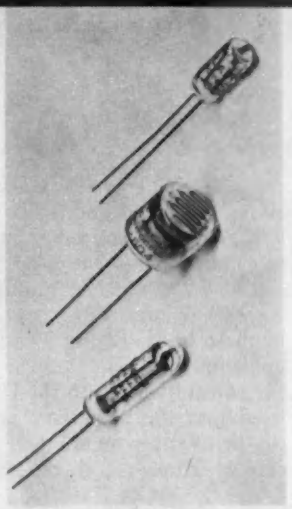


Solid State Radiation Sensors

INFRARED • E. M. WORMSER, Barnes Engineering Co.

LIGHT • R. A. FARRALL, Instrument Dept., General Electric Co.

NUCLEAR • P. F. DONOVAN, Bell Telephone Laboratories, Inc.



Clairex

From infrared to gamma rays, semiconductor detectors—small, sensitive, and efficient—are taking over the measurement of radiant energy. Here are the facts you need on the kinds of detectors available and where to use each.

INFRARED DETECTION

The hectic activity in semiconductors has reaped one unexpected byproduct: it has sharply stimulated the development of new infrared detection equipment so sensitive that these new instruments can measure infrared radiation of very low energy, whose wavelength is as long as 40 microns (40,000 Angstroms). One quality of semiconductor materials pure enough to make transistors and diodes is that they demonstrate unusually good optical qualities for handling infrared radiation. Materials such as silicon and germanium are very transparent to IR, so they can be used for windows and lenses; both have high indices of refraction in the IR range so they make efficient lenses; and because both have very sharp absorption edges (stop transmitting abruptly at wavelengths shorter than the "edge" wavelength) they are good filters.

In addition, the PN junction itself offers unusual capability as a detecting mechanism. Such a dedector can be as small as the head of a pin and still operate effectively. Flakes of other kinds of semiconductor materials called thermistors also make tiny but excellent IR detectors. This miniaturization is important in space technology, one of the fastest growing areas of infrared application.

These desirable qualities are incorporated into two types of detectors, the photo detector and the thermal detector. The energy of the infrared radiation to be detected determines which type to use (Figure 1).

If the radiation is high energy, i.e., short wavelength, the photons of infrared energy have enough energy to free an electron, or, in a semiconductor junction, release a hole-electron pair. The current produced is a measure of the intensity of radiation. That is the mechanism of the photo detector.

If the radiation is low energy infrared, however, a photon does not have the energy to free an electron, but it does agitate the electrons, raising the internal temperature. This is the mechanism of the thermal detector.

The photo detector

In the photo detector, the current or voltage generated is proportional to the number of photons of infrared radiation striking the detector. This effect is employed in detectors in three ways:

- Photoconductivity—radiation impinging on the detector sets up a current which is a measure of IR.
- Photovoltaic effect—radiation produces electron-hole pairs at a junction; concentration of charge tends to separate them and generate a voltage.
- Photoemissive effect—radiation is powerful enough to knock electrons right out of the detector material. The current of these free electrons is a measure of the intensity of radiation.

In general, photo detectors are more sensitive than thermal detectors and have very short response times. When cooled to the temperatures of liquid helium some of them become very sensitive to low energy radiation. But response is limited and not uniform.

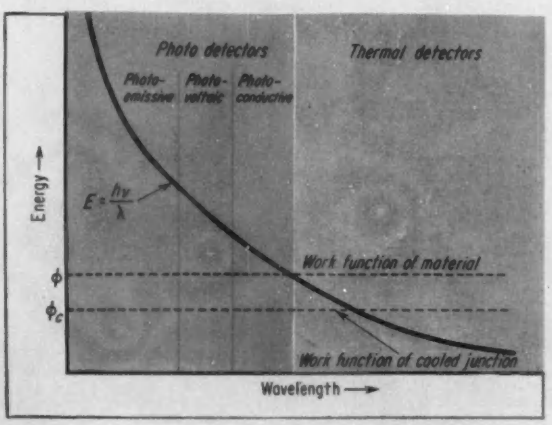


FIG. 1. Cooling a photo detector element lowers the work function of the material and makes it sensitive to longer wavelength radiation.

The Thermal detector

In a thermal detector, energy absorbed by a thin blackened surface causes a rise in temperature. Thermal detectors integrate the energy under an energy-wavelength curve. They are relatively slow devices (response time ranges from millisecs to tens of secs compared to the microsec response of photo detectors). The thermal detector has essentially uniform spectral response throughout the ultraviolet, visible, and IR regions.

There are four common methods of converting the temperature rise to a useful signal:

- Heating changes the detector's resistance and can modulate a current produced by a constant voltage. (This type is called a bolometer.)
- The detecting element is a thermocouple junction; voltage generated is a measure of radiation.
- Radiation heats a gas in a closed cell and in one type, the Golay cell, the change in pressure operates an optical lever to generate a reading.
- The detector is shaped like a thin bar, and expands when heated, moving a mechanical linkage.

One of the newest and most sensitive thermal detectors is a bolometer made of a flake of thermistor (semiconductor oxides) in contact with a germanium lens. This device may be an order of magnitude more sensitive than previously available detectors due to the focusing power of the lens. This combination has applications in orientation control systems of satellites and in industrial on-line gaging systems.

• • •

LIGHT SENSITIVE CELLS

Solid state light sensors—more sensitive, far smaller and lighter, and less wasteful of power than photoemissive vacuum tubes—have a multitude of military, industrial, and commercial uses. Today there are three basic types: photovoltaic, photoconductive, and photoswitching, Figure 2.

Photovoltaic sensors

Silicon and selenium photovoltaic cells generate a voltage proportional to incident light intensity. This is the only type of cell that can power electronic equipment directly. Si cells have a far broader response to sunlight or tungsten light than do Se cells, so their conversion efficiency is much higher. Si cells supply up to 40 ma when illuminated by bright sunlight, and one or more of these cells hooked in series-parallel are the best choice when high output is needed. On the other hand, the Se cell is the standard for qualitative analysis of light because this type of cell plus a filter can duplicate normal eye response. Se photovoltaic cells normally supply 200-800 microamp with 100 f-c illuminance.

The response time of typical Se cells is 20-30 microsec; Si cells have faster response, in the order of 2-3 microsec. At high speeds, output drops. Large cells are slower because of their capacitance.

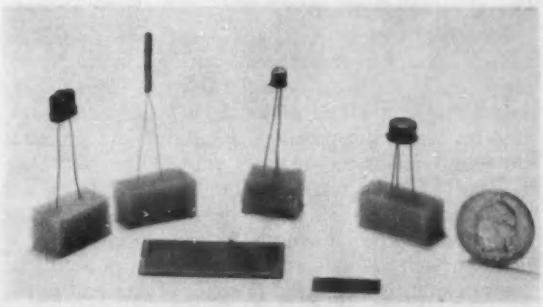


FIG. 2. Family of solid state light sensors: Front row, a General Electric Se photovoltaic cell and Hoffman Electronics Si photovoltaic cell; back row, a Texas Instruments phototransistor, a Sylvania photodiode, a Photran PNPN switch by Solid State Products, Inc., and a General Electric photoconductive cell.

Photoconductive devices

Photoconductive sensors come in three types. The first, the so-called photoconductive cell, is commonly made of cadmium sulphide or cadmium selenide, with resistance inversely proportional to light intensity. CdS cells follow normal visual response closely and have spectral peaks from 5,100 to 6,500 Angstroms. CdSe cells peak more in the red (7,000-8,000 Angstroms) with some response to 9,000 or 10,000 Angstroms.

CdS cells are less temperature sensitive than CdSe cells, but somewhat slower. The response time of either cell is in the 1-10 millisec range and inversely proportional to light level. Photoconductive cells can be used in low frequency choppers or counters but are not satisfactory for microsec switching.

The photoconductive cells used now are far more sensitive to weak illumination (they measure intensities of 0.001 f-c or less) than any other solid state photo sensors available. In total darkness the cells have a resistance in the order of hundreds of megohms. Photoconductive cells operate with up to 300 volts ac or dc, a major advantage over other photoconductive sensors.

Photodiodes, usually silicon or germanium, have response times in the order of 1 microsec with high illumination. They are used widely for rapid switching or counting, e.g., card readers for computers. Typical Si photodiodes have peak response at 9,000 Angstroms; Ge diodes peak in the IR at about 15,000 Angstroms, are sensitive back to 4,000 Angstroms.

Presently available photodiodes have an extremely small light sensitive junction and a lens to focus the light onto this area. Their highly directional response makes them ideal for position indication, since no external optics are needed. They have outputs in the microamp or low milliamp range.

The phototransistor is an extension of the photodiode in which light-generated current supplies base drive. With its built-in amplification, the phototransistor gives more output current per f-c than a photodiode. Temperature sensitivity makes phototransistors unsuitable for accurate measurement of light wavelength or intensity; they are better used to sense the presence or absence of light.

A photosensitive switch

Photoswitching sensors are PNPN light-controlled rectifiers. Light energy applied to the base region causes a change in resistance from the megohm level to a very few ohms. With a dc voltage source, once the photoswitch is turned on it will continue to conduct even with the light removed. With an ac voltage source, the switch will automatically return to the off condition.

With high illumination, switching times in the order of 1 microsec are possible. Some models can handle load powers as high as 40 watts to drive counters, relays, and similar controls directly. The light level at which switching takes place can be adjusted by varying the electrical bias.

NUCLEAR RADIATION DETECTORS

Silicon PN junction nuclear radiation detectors*, Figure 3, are smaller, lighter, and require less power than gas ionization chambers, and have much better energy resolution. When energetic charged particles (like αs and βs) enter the detector, they form electron-hole pairs at the expense of 3.5 eV of energy per pair (compared to 35 eV per pair in gas chambers). The electron-hole pairs are "swept out" by the reverse bias voltage maintained across the junction and charge the junction capacitance. This charge is measured with a low-noise charge integrating preamplifier whose output is relatively insensitive to the bias-sensitive junction capacitance. The best preamplifiers add noise equivalent to about 5 KeV; individual particles of this order of energy or lower are indetectable.

Neutrons are not charged particles and do not produce electron-hole pairs. However, a solid state detector can be adapted to measure neutron energy:

- Protons produced by elastic neutron collisions in a paraffine radiator may be measured after suitable collimation.
- Two detectors may be placed on either side of a piece of Li^6. Neutrons that enter the Li^6 form tritons and α particles which move toward opposite detectors. A coincidence is required. The sum of the detector readings is a known function of the neutron energy.

Collection time (rise time of the pulse) with solid state detectors is from 2 to 50 $\times 10^{-9}$ sec depending on, among other things, the detector capacitance and resistance and the electric field in the device. This is considerably faster than most other types of counters. Detectors range in area from 1 sq mm to 1 sq cm. It is essential that the impurity content of the semiconductor be very small. Otherwise, the electron-hole pairs will recombine before charging up the junction. The table indicates the best energy ranges and resolutions that have been achieved for several types of radiation.

WHAT SOLID STATE NUCLEAR DETECTORS CAN MEASURE

Radiation	Energy range	Energy resolution
α particles	$\leq$ 80 MeV	15 KeV @ 5 MeV or 0.3 percent
β particles (electrons)	$\leq$ 2-3 MeV	6 KeV @ 122 KeV
γ rays	$\leq$ 500 KeV	6 KeV @ 136 KeV
Neutrons	$\leq$ few MeV	$\approx$ 100 KeV
Protons	$\leq$ 20 MeV	20 KeV @ 5 MeV 50 KeV @ 12 MeV
Fission fragments	50-160 MeV	2 percent
Minimum ionizing particles	$\leq$ 1 MeV deposited	5-10 percent

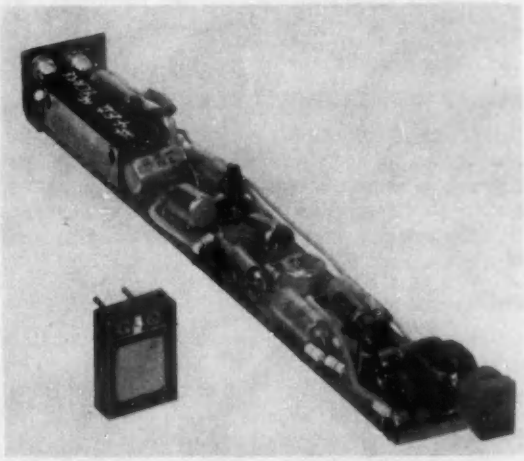


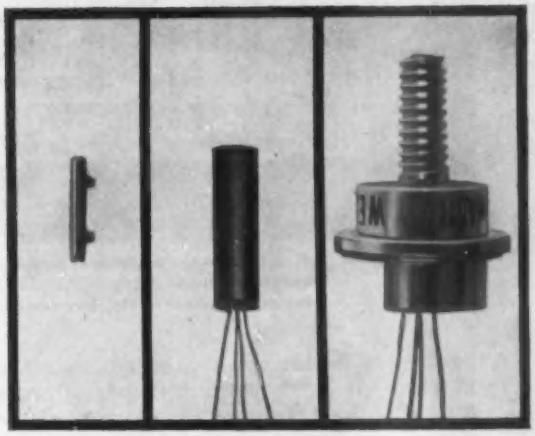
FIG. 3 Silicon nuclear particle detector and transistor preamplifier, both by Solid State Radiations, Inc.

Industrial uses of α, β, and δ radiation detectors include position indication (tracing, liquid level gages, etc.), and density and thickness gaging (the nature and amount of material between source and detector varies the reading). Neutrons and protons are found mainly in reactors and accelerators and in space. Fission fragments might prove useful for measuring small thicknesses because of their short range. Minimum ionizing particles are those that go right through the detector but produce a pulse; their measurement is important in space probes and satellites as well as in high energy particle physics.

* Makers include Oak Ridge Technical Enterprises Corp., RCA-Canada, Solid State Radiations, Inc., and the Semiconductor Div. of Hughes Aircraft Co.

Semiconductor Thermometers

ALLEN NUSSBAUM
Honeywell Research Center
Minneapolis-Honeywell Regulator Co.



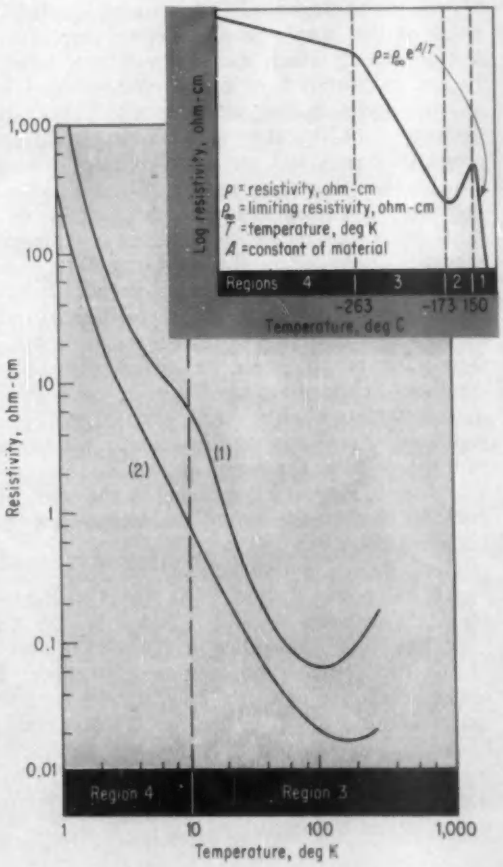
Semiconductor materials—particularly germanium—serve as well as temperature-sensing probes. This semiconductor material can be structured to fit exacting sensitivity and range requirements, especially for measurement of cryogenic temperatures.

Since semiconductor resistivity is strongly temperature dependent, semiconductor materials make excellent resistance thermometers. Both thermistor materials and germanium have been made into thermometers of various sizes and shapes, some of which are shown in the title photograph. Mixed-oxide thermistors have long been available and have well-established thermal sensing characteristics. These are discussed separately. Germanium, a relative newcomer to thermometry, possesses many advantages for temperature sensing. Its basic structure can be arranged to achieve a fairly constant and high degree of sensitivity over a wide range of temperatures, particularly at the cryogenic end of the scale. As shown above, the element is small, minimizing thermal lag and also making it suitable for probes. The four-lead configuration, used with appropriate circuitry, enables precise and stable temperature measurement.

The mechanism by which germanium translates temperature changes into resistance changes is dependent on the structure of the germanium crystal lattice. The element has four valence electrons that are normally bound to the atoms of the crystal lattice and are not free to conduct. When some of these atoms are replaced by atoms having five electrons (phosphorus, arsenic or antimony atoms, for example), then four of the impurity's electrons replace those of the germanium, leaving the fifth electron available for conduction. This doping converts the germanium to an N-type semiconductor. Semiconductors of the P-type are formed by doping with impurities having only three electrons (boron, gallium, aluminum, or indium) so that there is a missing electron or hole in the lattice.

Within a given germanium crystal, the conduction mechanism (and therefore resistance) is de-

FIG. 1. Variation of sensitivity in four thermal regions for a germanium sample (inset) and of two different samples in Regions 3 and 4.



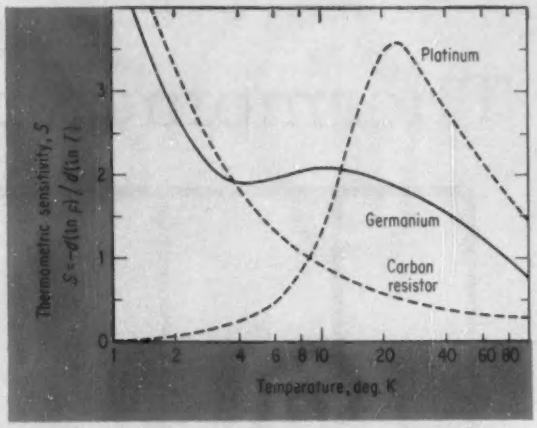


FIG. 2. Thermometric sensitivity of germanium thermometers is more nearly constant than that of platinum and carbon resistor thermometers.

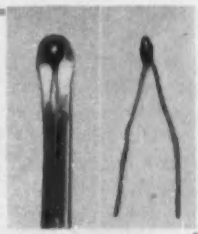
pendent on the thermal level or temperature region in which the germanium is operating, as shown in Figure 1 (inset). In Region 4, the conduction mechanism consists of electrons moving directly from one impurity atom to another. For this to occur, both types of impurity must be present, and the germanium is said to be partially compensated. When the germanium is doped with a large number of arsenic atoms and a smaller number of boron atoms, some electrons in the arsenic go into the holes in the boron, leaving empty spaces in the arsenic among which the electrons can move. In Region 3, liberation of excess electrons and holes requires declining amounts of energy, and resistivity decreases with increasing temperature. In Region 2, a reversal occurs, and the crystal behaves differently than in the other three regions. Thermal input has detached the excess electrons and holes from the host atoms, and resistivity increases as temperature increases. Behavior in Region 1 resembles that of Region 3, but the slope is much steeper. Region 1 is the range of temperatures where thermal energy imparted to the crystal detaches valence electrons from their parent atoms and makes them free to conduct. As the equation (Figure 1, inset) implies, a straight line should result from a plot of the logarithm of resistivity as a function of the temperature reciprocal in the region of validity (Region 1). The slope in Region 1 is specified by the constant A, and will be the same for all germanium samples at temperatures above 150 deg C.

Thus, doping affects behavior in Regions 2, 3, and 4, but not in Region 1. As shown in Figure 1, transition between Regions 4 and 3 can be either "hard" or "soft", depending on the relative amounts of the two compensating impurities present. The gradual transition of Curve 2 is desirable for a wide range (about 1 deg K to 100 deg K) thermometer. Curve 1 represents a thermometer designed to maximize the sensitivity in the range of 15 to 25 deg K, a range well suited to measuring the temperature of liquid hydrogen.

Sensitivity

Figure 2 compares the thermometric sensitivity curve of a germanium thermometer with curves for carbon resistor and platinum thermometers. This germanium thermometer, the same from which Curve 2, Figure 2, was made, has essentially constant sensitivity from 3 to 30 deg K. By contrast, the curve for the thermometer of Curve 1, Figure 2, would show a peak around 20 deg K.

Germanium can be arranged to give reasonable sensitivity from approximately 100 deg K downward. The actual resistance of the thermometer shown is about 400 ohms in liquid helium (4.2 deg K), and even at temperatures near 0.5 deg K the resistance is not too large for use with recording potentiometers and automatic controllers. Moreover, because germanium thermometers use a single crystal material, they repeat measurements accurately even with frequent cycling to room temperature. Temperature can be measured to within at least 1 percent. At temperatures near that of liquid helium, the use of vapor pressure thermometry permits calibration to 0.0001 deg K. In addition, temperature differentials can be measured to 0.0001 deg, using a precision potentiometer.



Thermistors as temperature probes

■ Thermistors come in a large variety of sizes and shapes, and are made principally from metallic oxides and silicon carbide, which show a large negative coefficient of resistance. The logarithm of resistivity for these materials, plotted as a function of reciprocal temperature, is only an approximately straight line, in contrast to the "linear" behavior of germanium. For positive-coefficient thermistors, silicon and samarium-doped barium titanate are used.

Within the usable range of thermistors, (about minus 100 deg C to about plus 400 deg C), resistance of a typical unit varies considerably. A thermistor with a room temperature resistance of 2,000 ohms will have a resistance of 80,000 ohms at minus 50 deg C and 8 ohms at plus 300 deg C. Since this range is beyond the capabilities of simple instruments, bridge circuits are often used. By switching from one scale to another, the total range is broken down into subranges. Accuracy is 1 percent of scale range. By using two thermistors in a bridge, temperature differences as small as 0.001 deg C can be measured.

Solid state research recently brought forth the optical maser, which can produce kilowatts of coherent light in a narrow beam that will someday soon carry fantastic quantities of information. Needed still are wide-band detectors and modulators that can make worthwhile use of a 500-million Mc visible carrier frequency.

LIGHT: A New Communication Medium

G. C. DACEY, Bell Telephone Laboratories, Inc.

The optical maser, also called the "laser", will soon make the extremely high frequencies of visible light available for new communication channels. The tremendous bandwidths possible at light frequencies can solve once and for all the problems of channel crowding that must be faced in the part of the electromagnetic spectrum now used for communications.

In fact, the promise of great bandwidths comes none too soon. Telephone engineers already project the possibility that density circuits of the future might have to carry the equivalent of 20,000 voice channels. Allowing 50,000 bits per sec for high quality pulse code modulation of a single voice channel, the high density telephone circuit alone will require a channel capacity of 10^9 bits per sec. And if a picture has to be transmitted along with each voice channel, the required circuit capacity could go as high as 10^{12} bits per sec. Compare this requirement for a single long-distance telephone channel with the maximum bandwidth of about 10^7 bits per sec on present microwave systems.

But the frequency range of visible light is in the hundreds of millions of megacycles per sec, so that there is theoretically room for thousands of such 20,000 channel telephone circuits simultaneously. Stated another way, the visible light region alone between 4,000 and 7,000 Angstrom units could contain as many as 80 million television channels.

Note that pulse code modulation was assumed in the example of the high density telephone channel. This is because PCM is the most likely form of modulation for future systems for a number of reasons, including compatibility with automatic data processing equipment. But the most important reason is that transmission media such as pairs of wires and waveguides can carry more information in coded binary form than in analog form because the greater resistance of PCM to noise and interference more than makes up for the greater bandwidth it requires. Further, PCM signals can be regenerated many times without degradation. And the availability of practically unlimited bandwidths will make the use of PCM much more attractive than it is already.

The maser makes light a carrier

The optical maser was first proposed by Schawlow and Townes in 1958 (Ref. 1) and has been experimentally demonstrated in several U.S. research laboratories during the past year. It is the first practical device that can produce coherent electromagnetic waves at the frequencies of visible light. Coherent waves have correlation of phase over large distances in space and over long intervals of time. Light from an optical maser is at least a million times more coherent than that which can be produced from any other light source.

Lack of coherence in an oscillator is harmful in

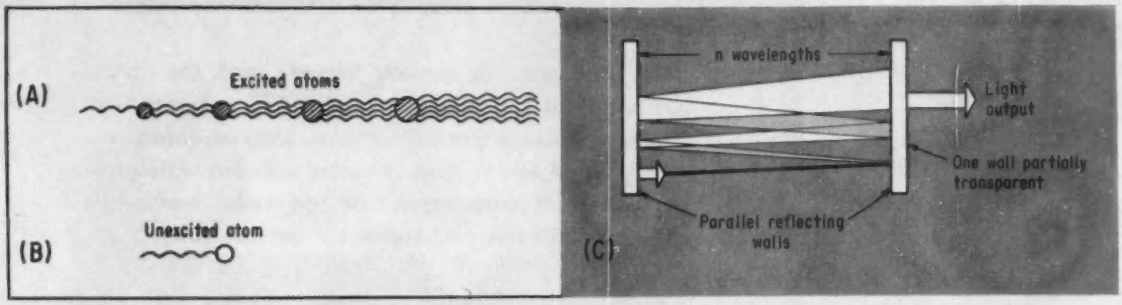
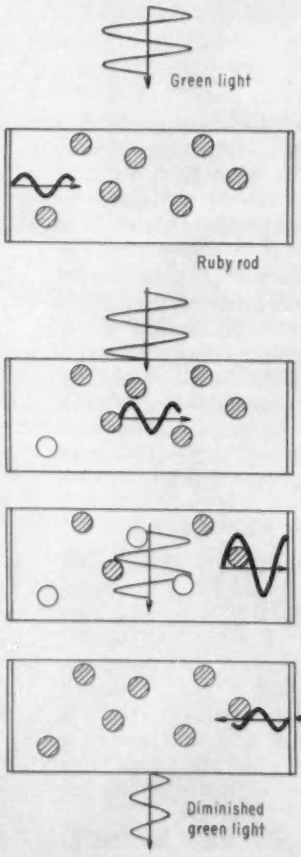


FIG. 1. A—Stimulated emission of radiation from atoms in excited energy state reinforces stimulating wave in proportion to number of atoms stimulated. B—Wave falling on unexcited atom is merely absorbed. C—Parallel reflecting walls of Fabry-Perot optical cavity cause growing light wave to pass back and forth through excited medium many times.

a communication system because it is equivalent to noise. Given a source of coherent light, all that is needed to make a communication system is a modulator, a transmission medium, and a detector. The challenge remaining is to develop these to take full advantage of the power and bandwidth that will be made available by the optical maser.

FIG. 2. *The principle of the optical maser.*



A—A ruby rod contains chromium atoms that absorb green light, make rubies red. The chromium atoms shown shaded have been raised to excited energy state by green "pumping" light from external source.

B—Red light falling on an excited chromium atom may stimulate that atom to emit its excess energy. This process produces red light in phase with the stimulating light and thus amplifies it.

C—Atoms which give up their excess energy are left in their lowest energy state (open circles) and must be re-excited by the pump. The amplified wave stimulates other excited atoms.

D—To stimulate more of the excited atoms the growing wave is reflected back and forth through the ruby. Red light that leaks through one mirror forms the usable output.

Optical maser oscillators have been demonstrated in a variety of substances. These include the ruby, calcium fluoride doped with various rare-earth atoms, and most recently a gaseous system involving a mixture of neon and helium. All of these devices operate on essentially the same principle. A material which is known to radiate light by stimulated emission is placed in an optical cavity (many wavelengths long) and excited by an external source. If enough of the atoms in the maser material are excited so that the stimulated emission of light exceeds the losses in the optical cavity, a standing wave of light builds up in the cavity.

The principles of the optical maser are illustrated by Figure 1. The wave in Figure 1A is shown growing in intensity due to in-phase reinforcement by stimulated emission. The unexcited atoms, as in Figure 1B, absorb light and reduce output. For maser action to take place, more atoms must be in the excited state than unexcited. The excitation comes from the external energy source, which has been called the "pump". Schawlow and Townes suggested that the pumped medium be placed between two parallel mirrors to form a Fabry-Perot optical cavity, as shown in Figure 1C. Only light that travels back and forth along the axis of the mirrors is amplified, as shown. Light traveling in any other direction soon misses the mirrors and is lost. Thus, the on-axis light is strongly amplified. If one of the mirrors is made partially transmitting, the light that emerges is coherent and parallel to the axis of the mirror system in a very narrow cone.

Consider the specific example of the ruby optical maser. A ruby is a single crystal of aluminum oxide in which a few of the aluminum atoms have been replaced by chromium atoms. The chromium atoms absorb green light; thus rubies are red. Also, some of the energy of the green absorbed light is re-emitted as red light and this phenomenon gives rise to the well-known red fluorescence of the ruby. Pumping with green light excites some of the chromium atoms to a higher energy level. The atoms rapidly relax to an intermediate level from which in turn

they are able to give up the remaining energy more slowly by emitting red light. Pumping, stimulated emission, and feedback are all displayed simultaneously in Figure 2. In the ruby maser the green pumping light must be very bright. Therefore it has so far been possible to operate ruby masers only on a pulse basis. The helium-neon gas maser, first described by A. Javan, W. R. Bennett, Jr., and D. R. Herriott of Bell Telephone Laboratories (Ref. 2), is pumped by a high frequency gas discharge and operates continuously.

These practical demonstrations have proved two other characteristics (besides coherency at high frequencies) that make the optical maser very promising for communications. First, it can produce very high energy outputs—measuring in kilowatts. Second, the output energy is confined to an extremely narrow cone with a spread of less than ½ deg at high power outputs. An experiment by Bell Laboratories scientists established communication over 23 miles using a ruby optical maser, see Figure 3. The beam was easily detectable with a photomultiplier tube at this distance, having spread to cover an area only 200 ft in diameter.

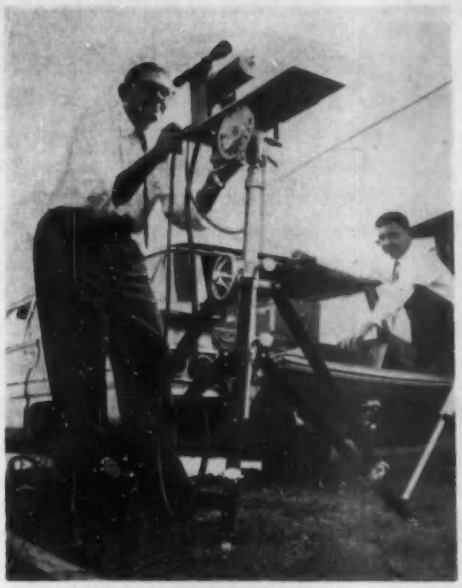


FIG. 3. Light from ruby optical maser in large cylinder on tripod was easily detected by photomultiplier at Murray Hill, N. J., 23 miles away from this experimental set-up at Holmdel, N. J. Beam in this experiment was unmodulated.

But modulation remains the problem

Before a complete light transmission system is practical, broad band detectors must be devised and modulation schemes must be worked out. The photomultiplier detectors used to date have a bandwidth limited to at most a few hundred megacycles. It should be possible, using traveling wave tube techniques, to make photoemissive detectors with bandwidths of several kilomegacycles. Solid state PN junction photodiodes can probably also be broadbanded. It is expected that one or both of these techniques will result in detectors capable of at least a few thousand megacycles bandwidth within the next few months.

A number of wide-band modulation schemes have been suggested and a few have been tried. In the gas optical maser, the radio frequency pump power to the gas discharge was modulated, resulting in amplitude modulation of the emitted light. The natural frequency of the atomic transition can be modulated by the application of electric fields (Stark effect). It is also feasible to modulate the natural frequency of the Fabry-Perot cavity by using piezoelectric crystals to vary the position of one mirror.

All such schemes, which alter the conditions of oscillation of the maser itself, seem to be limited in principle to a few megacycles bandwidth at most. Methods of modulating the light output of the maser so far offer greater bandwidths. Known techniques for modulating light sources do not require coherency and have been used for years to modulate ordinary sources. But transmission of information over useful distances was not practical until the maser provided a bright enough light source.

One light modulation scheme uses the Kerr electro-optic effect to vary the polarization of the light. I. P. Kaminow of Bell Telephone Laboratories recently used a transparent crystal of potassium dihydrogen phosphate (KDP) in a microwave cavity resonated at 9.25 kMc to match the velocity of the forward wave of the cavity standing wave with the velocity of the laser light passing through the KDP crystal (Ref. 2). The result was polarization-modulated light limited to a relatively narrow bandwidth (for light) of 60 Mc by the Q of the cavity. A pure traveling wave structure should give much wider bandwidths limited by the band over which the microwave and light velocities can be matched.

Many problems remain to be solved before a light transmission system is practical. There is, however, intense activity in many laboratories throughout the country on this subject. It may be that within the next few years the potentially vast channel capacity of light communications will be opened up for use.

REFERENCES

1. *INFRARED AND OPTICAL MASERS*, A. L. Schawlow and C. H. Townes, "Physical Review", Vol. 112, No. 6, pp. 1940-1949, December 1958.
2. *POPULATION INVERSION AND CONTINUOUS OPTICAL MASER OSCILLATION IN A GAS DISCHARGE CONTAINING A HE-NE MIXTURE*, A. Javan, W. R. Bennett, Jr., and D. R. Herriott, "Physical Review Letters", Vol. 6, No. 3, February 1, 1961.
3. *MICROWAVE MODULATION OF THE ELECTRO-OPTIC EFFECT IN KH_2PO_4*, I. P. Kaminow, "Physical Review Letters", Vol. 6, No. 10, May 1961, pp. 528-530.

Solid state memory and logic techniques, developed originally for the digital computer, have now been assimilated into the control system. This first article on decision making and storage considers the memory function in all its guises in control systems and the solid state memory devices that fit the various needs. The second article shows how computer-inspired logic circuits are developing new capabilities for control. The third views cryotronics as a memory and logic technique.

Where Solid State Fits Into Control Memory

E. J. KOMPASS, Control Engineering

Without memory, the very idea of control is meaningless. In the simplest instance of regulating some process variable to a constant value, the reference constant must be remembered for as long as regulation is needed. But even the reference value itself has to be recalled from memory as a good one from some previous experience or experiment with the controlled process.

As control systems develop, from the fixed setpoint (static) regulator to higher forms that track changing values and adapt control relationships to changing conditions, the requirements placed on memory devices grow more difficult. To make a static memory with a long life is simple. To make a memory that can change its stored value thousands or millions of times at high speed and last long is far from simple. The approach has been to reduce the energy stored in—and consequently the energy available from—memory devices. At the highest speeds electronics provides the only answer, and solid state devices promise the longest life and the best reliability.

Solid state memories can have very low over-all power requirements too, and therefore must be considered seriously for the memory job even where speed is not important. Solid state implementation is the trend for the future in every instance of control memory. A search among all the important elements usually found in control systems discovers memory in some surprising places, see Figure 1.

Control reference memory

The primary memory in any control system is the reference memory. This memory must exist, even in simple regulating systems, as the setpoint at which the controlled variable is to be maintained. It must also exist in the most complex control systems, though there may be many such setpoints and they can change quickly.

In the simpler systems the control point is static, and the reference memory can be constructed of relatively simple mechanical and electromechanical devices like levers, potentiometers, and synchro control transformers. Wearout failures are unlikely because the stored value is seldom changed. Purely mechanical devices can have very long life in such applications. However, power required to change the setpoint can be considerable and, in some missile and satellite applications, too great.

For setpoint memory applications, the prime virtue of solid state memory techniques is that they can be reset electrically at low power. Of the solid state techniques practical for storing analog levels, the one most directly comparable with the potentiometer is the so-called transfluxor, Figure 2. The transfluxor, a multiple aperture ferrite device, works on the general principle of the magnetic amplifier: a dc control signal sets the level of an ac current output by controlling the permeability of the leg of

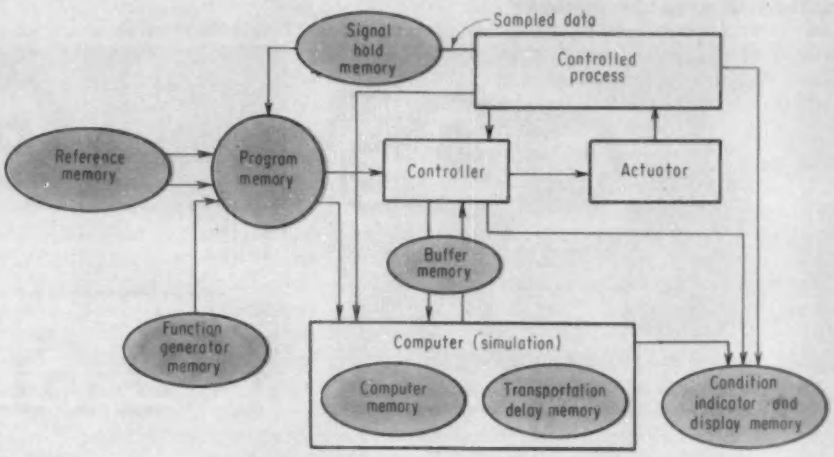


FIG. 1. The major kinds of memory in control systems. The location of the various functions shown is typical only.

the ferrite core that includes the output winding. The ferrite core of the transfluxor will "remember" the latest dc input level applied. The set input need be only momentary, so stored values can be changed at rates up to 100 kc (Ref. 1).

A transfluxor can control only ac outputs (or pulsed dc). The ac output can be rectified to dc by solid state diodes. Transfluxors are available with ac output currents of hundreds of milliamps, linear with respect to dc set levels within 3 percent. Feedback can be applied around the transfluxor circuit during the set operation to make the linearity 0.5 percent or better. The output rectifiers can be included in this feedback loop to make a high linearity dc storage device. No temperature compensation is necessary from 10 to 50 deg C. Output powers range from 0.1 watt to a few watts.

The ferrite transfluxor will remember its set level indefinitely. It is a nonvolatile memory and hence will not lose its stored value if the ac energizing power fails. When power returns after a failure, the reference value stored is unchanged. In this respect, the transfluxor is again just like the electromechanical potentiometer that it can replace.

Another solid state circuit able to store analog voltage levels is the transistorized version of the Miller integrator, Figure 3. Like its vacuum tube predecessor, it stores the voltage to be remembered as the charge on a capacitor. The Miller circuit places the capacitor in the negative feedback loop of a high gain amplifier and effectively multiplies the value of the capacitance by the gain of the amplifier plus one. Thus, discharge time constants of several days are possible with practical size components. The value stored in an integrator memory can be changed quickly and readout is nondestructive.

However, the circuit has several disadvantages. For one thing, a high gain transistorized amplifier may be expensive for a single memory function. For another, the memory is volatile; the stored value is lost if power supplies fail. The one disadvantage that may place the transistorized Miller integrator

ANALOG SIGNAL MEMORIES

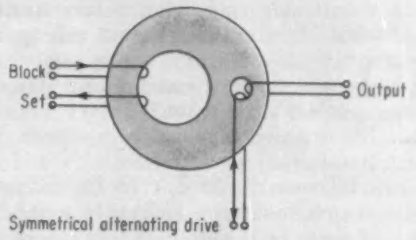


FIG. 2. A two aperture ferrite transfluxor can remember analog level applied momentarily at set input.

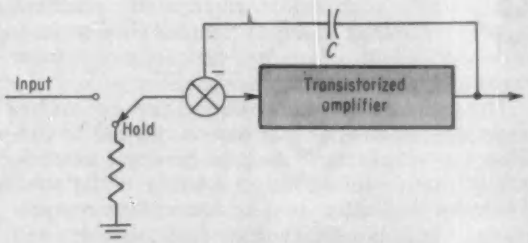


FIG. 3. Integrator circuit with transistorized operational amplifier can provide analog memory for short periods.

beyond consideration for some applications is that its memory is quite short in spite of large time constants. Practical circuits will store an input analog value to within a few percent for only a few hours.

Function generator memory

Another memory required in many control systems is one able to store a special function of one of the problem variables for combination with other signals. Special function generators in analog control systems have often been electromechanical, such as wound rotor type sine-cosine resolvers or potentiom-

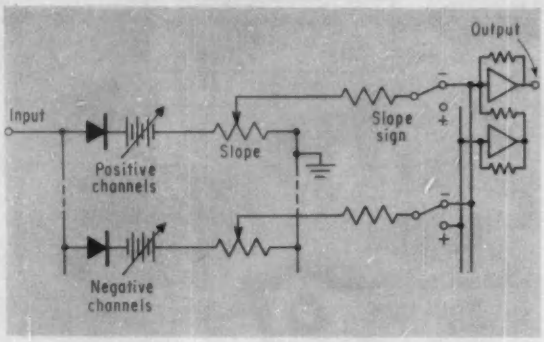


FIG. 4. Universal function generator based on semiconductor diodes can remember arbitrary functions.

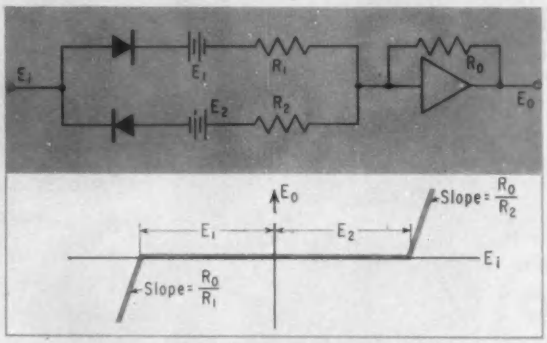


FIG. 5. Special functions can be stored easily in simple diode circuits like this one for backlash function.

eters with specially shaped winding cards. Detectors and pickoffs in such function generators can be replaced with solid state devices, but this approach does not avoid the mechanical input requirements. So far, sine-cosine resolvers based on the Hall effect also require a shaft angle input.

A number of universal function generators based on electromechanical devices have also had wide use. Curve followers of various kinds use conductive, capacitive, or photosensitive pickups to sense drawn curves, and again solid state detectors can be used. The most popular precision universal function generators employ networks of semiconductor diodes and potentiometers, Figure 4. Such generators produce output voltages that are arbitrary functions of an input voltage in any of the four polarity quadrants. Special circuits are easily designed to remember specific functions such as backlash, Figure 5.

The use of nonlinear characteristics for control component or circuit compensation can also be considered a special case of function generator memory. A solid state form of such a memory is the semiconductor thermistor, used for temperature compensation: heat is the independent variable and resistance is the dependent variable. Solid state thermoelectric devices based on the Peltier effect can also be used this way. The functions produced by such devices are the results of solid state processes that are not otherwise variable except by changing the atomic structure of the materials themselves, so their usefulness as function memories is fortuitous.

Program memories

The reference level for the simple control system can have several manually operated, switch selected values, but the trend in some newer control systems is to program multiple functions or operations that can occur over long periods and are thus not conducive to manual operation. A good example is the automatic switching in of a complete special sequence to accommodate an emergency condition.

The sequence of operations for the normal as well as the emergency routines must be stored in a program memory. There are two kinds of program memories: unit programmers and distributed programmers. In the first, the commands for the complete cycle of sequential operations are concentrated in a single device like a master cycle timer, or a magnetic or punched tape reader. In the second, the complete cycle is distributed among a number of program devices, each of which might control a particular section or function of the controlled process (Ref. 2).

No single solid state phenomenon or device provides a complete programmer function, so completely solid state programmers must be built up in circuits that combine memory and logic. In a simple time-sequenced unit programmer, the logic might consist solely of gates opened by pulses from a counter. The gates can be semiconductor diode circuits and the counter can be transistor flip-flops, as in Figure 6. The flip-flops provide a basic memory function, but in this case they merely accumulate the count of clock pulses and store a code for time from one pulse until the next. The diode gates form a decoding matrix for the counter's binary coded output. The circuit can be redrawn in the form shown in Figure 7 as a matrix memory.

In general, in a timer-actuated program an output pulse is wanted only at certain specified times or counts. The memory for the program, the times at which output is needed, is built into the wiring of the binary-decimal decoding matrix and is not provided by the circuits that energize the matrix, even if they also involve memory functions.

A wired diode matrix is therefore a special kind of fixed program memory if the inputs are energized in a stated sequence. If the inputs are not scanned in a fixed sequence, but can appear in any sequence, the matrix is merely a decoder. A decoder can be a part of a distributed program memory, however.

The memory of the program in the diode matrix

is in the positioning of the diodes. If the diodes were located at every matrix position with a switch for each diode, the resulting circuit would be a universal matrix in which the program stored could be changed by opening and closing the switches, thereby inserting diodes at different places in the matrix. Such a universal program memory has a second level of memory in the form of switches.

A number of solid state devices can replace both the diode and the switch at each position of the matrix memory. The ferrite magnetic core is the best known because of its wide use in digital computer memories (Refs. 3 and 4). (A digital computer stores its operating program in one section of its main core memory, and working data and partial results in another section of the same matrix.) Figure 8 shows a typical arrangement of ferrite cores in a memory matrix. The direction of the core's magnetic polarization represents either a binary 1 or 0. The core is thus analogous to a switch which can be closed or open. The magnetic state of the ferrite core can thus be thought of as representing the presence of absence of diodes in the more obvious diode matrix. An output can be had from an intersection in the matrix only if that particular core has presently stored a binary 1, just as an output can be had in the diode matrix only if a diode is present at the intersection selected.

A basic difference between the diode-switch matrix and the ferrite core memory is that the ferrite core readout is destructive. The stored state of magnetization is determined by applying readout signals that would switch the core to the 0 state. If the core is already in the 0 state, the output voltage induced in the sense or readout winding is very small. If the core is storing a 1, the core must switch its state and the output in the readout winding is relatively large. Ferrite core memories require circuits that automatically rewrite stored 1's immediately after readout. A complete memory cycle includes the rewrite time, which is generally somewhat longer than the readout or access time. Typical ferrite core memories have cycle times in the order of a few microseconds. Techniques for partial switching of ferrite cores (rather than switching to saturation) store smaller energies and can have cycle times down to 0.1 microsec or less and reducing core volume can shorten cycle time still further.

The high speed of the ferrite core memory is usually not any particular advantage for control system program memories (unless very large amounts of computation must be done to develop predicted conditions), and the destructive nature of the readout is a distinct disadvantage.

The multiple aperture ferrite device is one answer for nondestructive readout. Figure 9 is an array of transfluxors, with write address lines threaded through one set of apertures and read address lines through the other (Ref. 5). All connections to the write apertures can be removed after the program is stored so that it cannot be changed accidentally.

An even safer approach for nondestructive readout is the one taken by Manchester-Ferranti in their Atlas computer to store fixed constants. Ferrite slugs are inserted manually into a wire mesh to represent binary 1's. This solution is directly analogous to the placement of diodes in the diode matrix, except that expensive switches and soldering of components are not necessary.

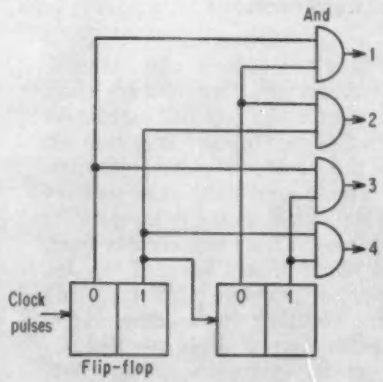
Computer memories

So far, computers used for industrial control have followed the design trends of general purpose computers. Although computers have capitalized on the nonvolatile core memory, the destructive readout problem has been avoided rather than faced in most cases. The trend in computer circuits in the past has predicted that in control systems, so for the long range view it ought to be watched. The continuing trend in computer memories is to higher speed and more capacity using solid state techniques.

Thin films of permalloy and thick films, cryotron thin films, tunnel diodes, and ferroelectric crystals—all promise to increase memory speed by two or three orders of magnitude over present cores. Thin film techniques also offer fantastic component densities, so that very large capacity memories can be packaged into a small space.

Almost the entire thin film technology development is being supported by computer manufacturers because memories must be made faster. Speed is approaching the point where propagation velocities on wire of 0.5 ft per nanosec cause enough time delay between computing elements that gates may not work. The only way to get computing speeds of 10 nanosec per cycle or less is to reduce computer size. Entire thin film circuits, including permalloy films that operate at room temperatures (Ref. 6) and cryotron films that operate near 4 deg K (Ref. 7), can be vacuum deposited with component densities of 1,000 per sq in. or more. Both types can switch in as little as 1 nanosec. But permalloy films have no gain and cryotrons do, page 160. Thus, logic cir-

FIG. 6. Program timer consisting of AND gates driven by clock pulse counter.



Output	Count in flip-flop (1's side)
1	00
2	01
3	10
4	11

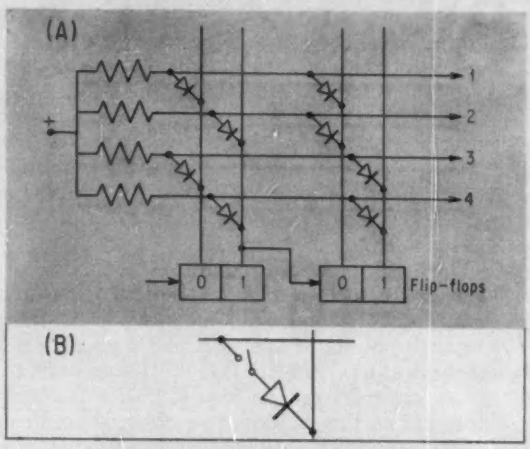


FIG. 7. A—Circuit of Figure 6 redrawn as diode matrix. B—Matrix can be made universal by providing a diode and a switch at every matrix crosspoint.

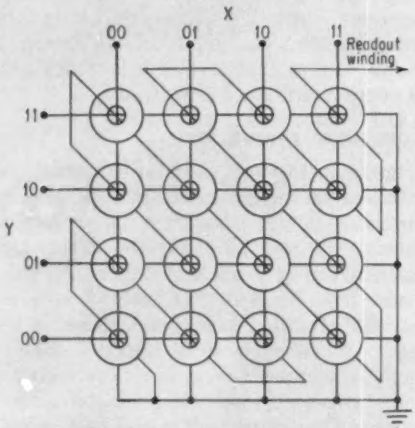


FIG. 8. Typical 4 x 4 ferrite core matrix. Readout is destructive, data must be rewritten.

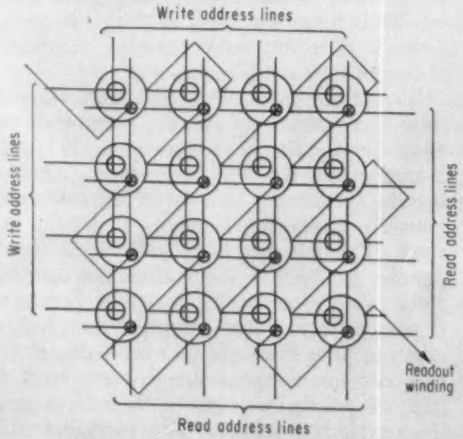


FIG. 9. Typical 4 x 4 transfluxor MAD memory matrix. Readout is nondestructive.

cuits can be made up from cryotrons, while magnetic thin films are limited to memory.

CBS Laboratories recently announced a cylindrical thick film memory element in which the film is 30,000 Angstroms thick instead of the 1,000 to 4,000 Angstrom thicknesses needed for the usual thin film dots. The thicker film makes fabrication control much easier. The real advantages are high output (200 millivolts compared to the 5 or 10 millivolts practical with thin film dots) and inherent nondestructive readout. The thick film device is somewhat slower: cycle times are 15 or 20 nanosec.

Tunnel diodes hit a peak of interest about two years ago, then interest dwindled. But the tunnel diode may yet be a factor in computer memories (and logic, because it has gain). It is about the fastest switch at the moment; available tunnel diodes can switch in 0.5 manosec and some have been built with switching times of about 0.05 nanosec. A typical tunnel diode memory cell is shown in Figure 10. Because the tunnel diode is naturally bistable, it is only necessary to place a resistive load across the diode. Splitting this load into X and Y selection resistors permits selecting the particular diode in a matrix. RCA has built an 8 x 8 tunnel diode memory matrix as part of their project to develop 1,000 Mc computer circuitry for the Navy, see Figure 11. This memory was cycled at 100 nanosec using common transistor drivers. Readout is destructive.

Ferroelectric crystals such as barium titanate have also been recently proposed by the Naval Ordnance Laboratory as memory elements for computers. A single crystal can be made into a matrix by a series of parallel lines scribed on one face and a corresponding set of lines at right angles on the other face. The crosspoints would then act as memory cells, storing an electric charge. Readout would be destructive. A problem seems to be crystal heating.

National Cash Register has a very interesting memory device that depends on a change of color state due to quantum mechanical effects in a photochromic dye. The change is impressed by a light spot focused on the dye layer, and present optics can reach packing densities of a million bits per sq in. Switching speeds are in fractional microseconds.

Buffer and signal hold memory

Buffer memories accept information for storage at one rate and read it out at another rate. Thus in computer communication links, information transmitted at 1,000 bits per sec by a punched tape reader can be stored in a buffer memory and later read out of the buffer into the computer memory at 500,000 bits per sec. Almost every solid state memory technique can find application in buffer memory.

Buffering rates are much slower in control systems. One use is to hold values of data sampled simultaneously on a number of channels so that all data can be put in time sequence by a commutating switch for transmission over a single telemetering channel. The input data in such a system could

TUNNEL DIODE MEMORY

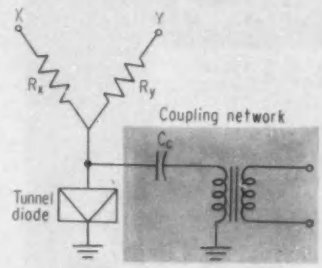


FIG. 10. Tunnel diode memory elements like this have been assembled into 8 x 8 arrays and driven at 100 nanosec cycle time.

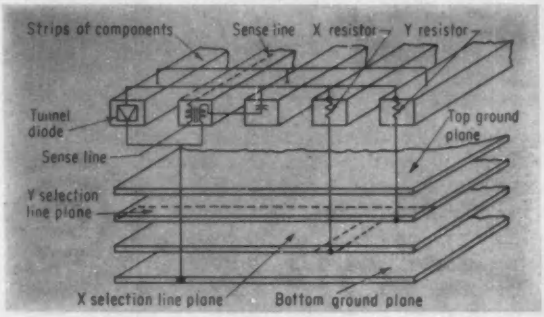


FIG. 11. Technique used to construct a tunnel diode memory plane.

be either analog or digital, though the trend today is to digitize data as close to analog measurement devices as possible. Typical commutation rates with electromechanical commutators are a few hundred samples per second, and the slower solid state memory techniques are practical. Circuit simplicity and low cost with reliability would be goals.

Signal hold memories are also used in sampled-data control systems to store a measured or calculated value from one sample time to the next.

Signal delay memory

Signal delay is another form of memory that sometimes appears in control systems. Any process that involves moving matter (or information) from one place to another inherently includes transportation lags. Transportation lag is a true time delay in the appearance of a signal at another point in a system. Its effect on controllability of a process can be extremely important. True analog signal time delay can be simulated by a distortionless memory. But the problem is that the memory must be able to accept samples at a rate that is several times the highest frequency of interest in the signal for a time at least equal to the maximum delay possible in the process. These requirements can lead to extremely large capacity memories in many processes, where delays can be hours or even days.

Practical time delay memories have compromised the ideal even for delays of the order of a few minutes by storing fewer samples of the most significant low frequencies after filtering the higher ones to remove the possibility of ambiguity. Most of the approaches have been electromechanical, such as storing sequential signal values on capacitors scanned by a commutating switch. The most practical for time delay of relatively wide band signals for long periods has been the magnetic tape recorder, using pulse width modulation to store analog signals.

Signal delay is one control memory problem that solid state devices hold no solution for as yet, though some of the electronic techniques for shorter time delays, such as the bucket brigade circuit and the so-called Pade approximation circuit, can be implemented with transistorized circuits.

Digital signal delays also occur in control systems in which a single pulse or a coded number may have to be delayed for some specified time. Such signals can be stored away in any digital memory device and recalled when needed by a signal from a timer (counter) or the completion of some phase of a process function. Digital signals can be delayed in a shift register (a set of binary memory cells arranged so that all stored data shifts by one position for each shift pulse input) to synchronize data in the register with position in the system.

Indicator and display memory

Another memory function needed in almost every control system is a visual indication of process or control system conditions. Displays based on coupling solid state electroluminescent lamps with solid state photoconductive cells electrically in series have an inherent binary memory capability. A pulse of light on the photoconductive portion of the EL-PC assembly will lower its resistance and allow an ac supply to light the EL lamp. Light from the lamp will then hold the PC resistance low and thereby keep itself lighted. The PC element can be shielded from ambient room lighting and triggered by another EL source specially placed for that purpose. An article reviewing solid state displays, with and without memory, starts on page 180.

REFERENCES

1. *THE TRANSFLUXOR*, J. A. Rajchman and A. W. Lo, "Poceedings of the IRE", March 1956, pp. 321-332.
2. *PROGRAM CONTROLLERS SET THE PULSEBEAT OF INDUSTRY*, J. D. Cooney, "Control Engineering", Sept. 1958, pp. 116-117, (plus other articles in issue).
3. *A COINCIDENT CURRENT MAGNETIC MEMORY CELL FOR THE STORAGE OF DIGITAL INFORMATION*, W. N Papian, "Proceedings of the IRE", April 1952, pp. 475-478.
4. *THE COMPUTER'S MEMORY*, F. Fowler, Jr., "Control Engineering", May 1956, pp. 93-101.
5. *A MULTILOAD TRANSFLUXOR MEMORY*, D. G. Hammel, W. L. Morgan, and R. D. Sidnam, "Proceedings of the Western Joint Computer Conference", San Francisco, Calif., March 1959.
6. *THIN FILM MEMORIES*, E. E Bittmann, "IRE Transactions on Electronic Computers", June 1959.
7. *SUPERCONDUCTING COMPUTERS*, W. B. Ittner, III, and C J. Kraus, "Scientific American", July 1961, pp. 125-136.

New Approaches to Control Logic

Transistor-diode circuits made digital logic reliable enough for widespread use in control systems. Now, newer solid state logic devices are making circuits simpler. Some can control power directly.

JAMES B. HANGSTEFER, Solid State Products, Inc.

It took solid state switching and memory devices to put digital logic in control systems. The reason is that control systems, both military and industrial, demand a high degree of reliability and semiconductor devices provide reliability with circuit simplicity. The result is that digital logic is the control engineer's newest and most versatile design medium . . . it can be both the bricks and the mortar in a control system.

Digital techniques offer new dimensions of flexibility to the control system designer. This versatility has been available to control engineers for many years through the binary characteristics of the electromagnetic relay, and simple relay logic has been widely used. But the relay has several well-known shortcomings that usually preclude its use in complex systems requiring high reliability.

So it was the advent of semiconductor switching devices that gave the real impetus to the application of logic techniques in control.

Where logic techniques fit into control

Logic techniques are being employed to advantage in virtually every part of modern control systems. In fact, the scope of application can be considerably broader in control systems than in conventional computers. A computer's primary objective is to make computations, and it can usually be designed around a relatively small number of basic logic circuits. Three basic circuits (see Figure 1) the OR, AND, and NOT or combinations and variations of these such as the NOR (OR-NOT) can be used to build almost all computer logic circuits. In control systems, computation is only one function among many others. Scores of other logic circuits are needed in the information gathering, decision making, and decision implementing functions of control systems. In addition, because control systems are usually hybrids (i.e., combine both analog and digital techniques) there is frequent need for analog-to-digital and digital-to-analog conversion logic.

Some specific areas where logic techniques have application in control systems include: programming, signal conditioning, sampling, computation, monitoring, counting, and digital servos. These areas of application of logic techniques are by no means all-inclusive. They do, however, indicate the usefulness and scope of digital logic techniques in control systems.

Solid state devices for control logic

The solid state devices used in control logic circuits set the conditions for circuit designs and normally determine the performance capability of the circuit. Three types of semiconductor devices are commonly used as the basic circuit building blocks. These are diodes, transistors, and PNPN switches. Both germanium and silicon types are available, and the choice is usually dictated by circuit requirements and cost. There are many differences in properties between germanium and silicon devices, but the most significant are the higher temperature and higher voltage capabilities of silicon. These two factors often make circuit design simpler and more reliable when silicon devices are used. Silicon devices have been more expensive than germanium, but the differential has been steadily shrinking. Today, a balance of cost against performance frequently decides in favor of silicon devices for industrial as well as military systems.

Transistors

The transistor is one of the two active solid state elements (the other is the PNPN switch) commonly used in control logic circuits. Transistors are analog devices in the sense that their output is a direction function of their input. They are useful as linear amplifiers as well as switches. In digital logic systems, the switching property is paramount. Many basic digital logic circuits have been designed around transistors. Some are illustrated in Figure 1.

PNPN switches

PNPN switches are the newest devices to be used advantageously as active elements in control logic circuits. They have several unique and useful prop-

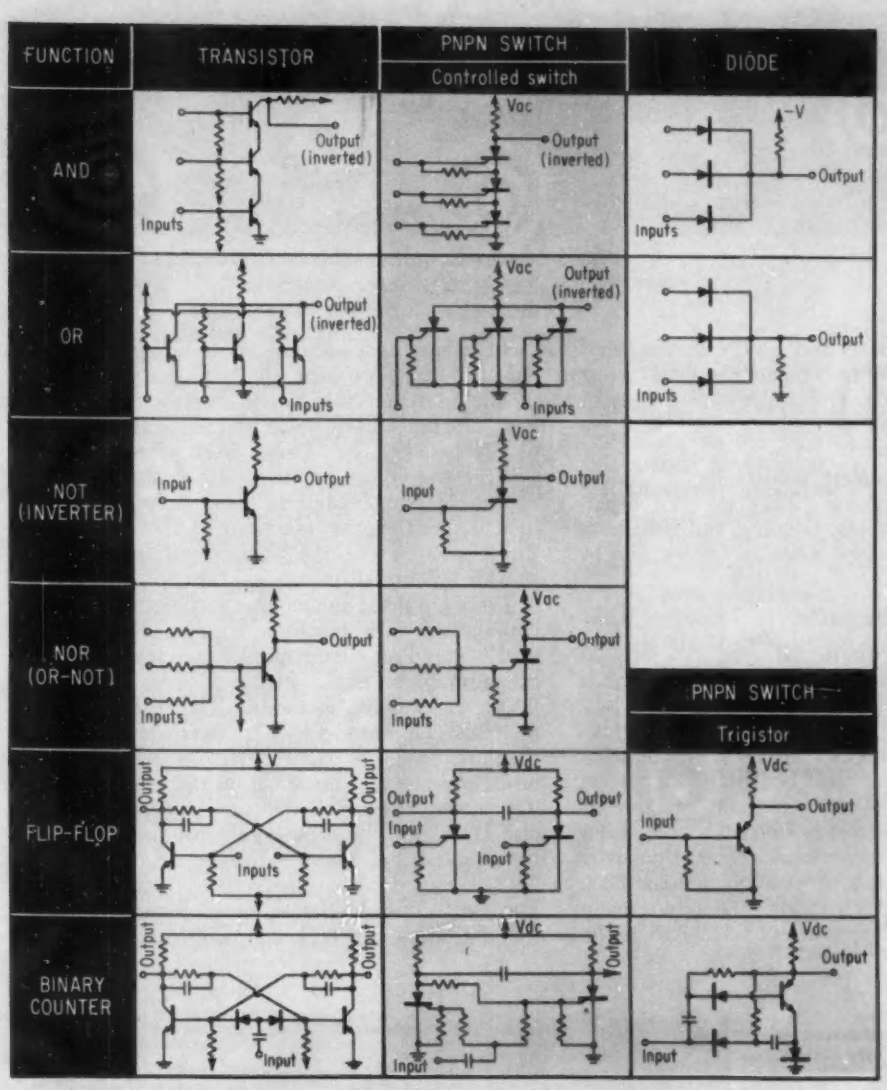


FIG. 1. SOME BASIC SEMICONDUCTOR LOGIC CIRCUITS

erties that allow new approaches in solving many control circuit problems. First, PNPN devices have the property of binary memory, and can often replace more complex transistor flip-flops in data accumulators and other memory applications. Second, PNPN switches have extremely high gain and high triggering sensitivity. They can often be used in place of multistage transistor amplifiers. Third, these devices can operate over a much wider range of both current (1 milliamp to 20 amps) and voltage (3 volts to 200 volts) than comparable-size transistors. This makes possible dual functions in a single active element. For example, both logical functions and output actuation can often be accomplished by a single PNPN device (see Figure 5). Finally, in many control logic functions ac power supplies can substantially simplify circuits and eliminate the need for expensive dc power.

Three classes of PNPN switches are presently available. One class is called the controlled switch (or controlled rectifier) and is thyratron-like—the gate terminal can be used only to turn it on. A second class, called the Trigistor, can be turned on and off at the gate terminal. The third class, the Photran, is a controlled switch that can be gated optically as well as electrically.

PNPN devices, partly because they are a more recent development, have been somewhat more expensive than comparable transistors. In spite of this, it is frequently more economical to use them because of their higher performance and the circuit simplification possible. When comparing econ-

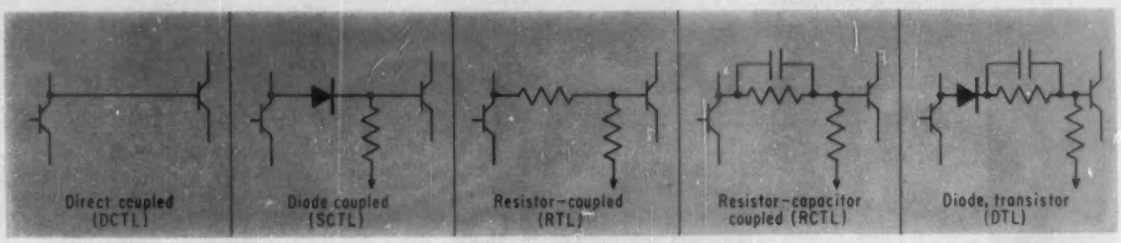


FIG. 2. Interstage coupling methods used with transistor logic.

omies between transistors and PNPN devices, it is very much worth while to compare the total circuit cost rather than the cost of active elements only.

Diodes

Diodes are the simplest semiconductor devices employed in logic systems. They are used extensively for gating, clamping, isolating, and detecting. The two basic diode logic gates are shown also in Figure 1.

Control logic circuits

Control systems with digital logic can vary in complexity from a simple monitor that may be a single circuit to large computer process control systems. Most systems, however, fall somewhere between these two extremes. Because of the wide variety of problems that must be handled in control systems, there is usually a significant amount of special circuit design necessary for each system, even though standard circuits are used whenever possible.

Figure 1 is a tabulation of some of the basic logic circuits useful in control systems. There are many variations of each of these that can be used to implement almost any desired control logic function.

For computation logic, the transistor NOR is one of the most versatile circuits. Any computation logic function can be made by various combinations of the basic NOR. Using NOR elements exclusively, however, can be the most expensive approach in some systems because of the complexity involved in achieving the other functions. Often, diode gates in conjunction with the NOT circuit and a flip-flop provide a more satisfactory solution.

There are many interconnection methods used in conjunction with transistor logic. The choice is usually based on circuit speed requirements and the transistor to be used. Figure 2 shows five typical interstage coupling methods. The direct coupling methods (DCTL and SCTL) are the simplest, but they impose severe requirements on transistor properties and provide very small output voltage swings. The network coupled approaches (RTL, RCTL, and DTL) are the most commonly used. RTL is the simplest, but it also is the slowest. RCTL and DTL are used when higher speed is a basic goal. For most control systems, speed requirements are not too severe and RTL coupling is practical.

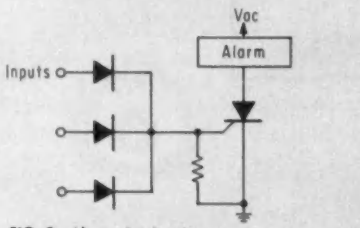


FIG. 3. Alarm circuit using controlled switch has OR input.

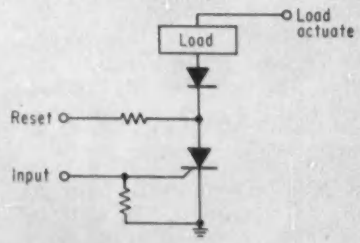


FIG. 5. Controlled switch provides memory plus output power.

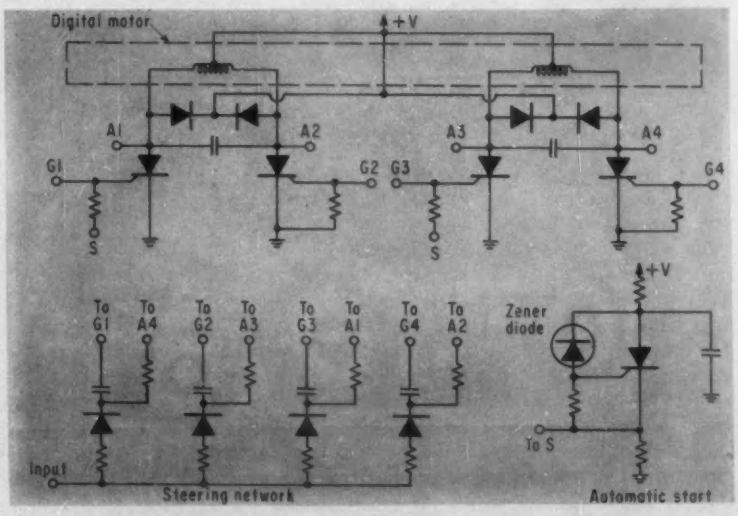


FIG. 4. Stepping motor driving circuit using controlled switches.

Controlled switch circuits operating from an ac power supply are unique and are applied differently than the diode or transistor circuits. They are not used in computation logic, but rather in output sections of a system. The circuit of Figure 3 is the basic NOT with its output driving an alarm indicator (lamp, buzzer, relay, etc.). Fault signals (from other logic elements or sensors) are applied to the input diode gate from several sources. The circuit will actuate the alarm whenever fault signals are present and will be quiescent when input signals are absent. The input can be converted easily from OR to AND if desired. The circuit can be made to latch (continue to actuate the alarm after fault signal stops) by simply using a dc power supply that must be interrupted to unlatch.

The controlled switch flip-flop circuit is useful as an output circuit in digital servo systems. By adding an input pulse steering network and automatic startup circuit, the flip-flop will directly drive the coils of a digital motor (stepping motor) in the proper sequence. Figure 4 shows a drive circuit of this type for single direction rotation. By adding a second steering network, rotation in either direction can be achieved.

The Trigistor flip-flop circuit shown in Figure 1 has a unique advantage over transistor flip-flops. When this circuit is off, it does not draw current. This feature can be extremely useful in satellite and missile systems, where long-time operating requirements make power conservation vital.

In applications such as print hammer driving, tape punching, or solenoid driving, the controlled switch can perform the dual role of driving element and memory cell in an output register, Figure 5. A positive pulse at the input will "set" the controlled switch. The reset circuit provides a small dc holding current. The load is actuated at any later time by applying a power pulse to the load actuate bus. The circuit is reset by temporarily removing voltage from the reset bus. This circuit is useful whenever information comes to the output at different times but all outputs should be read out in parallel.

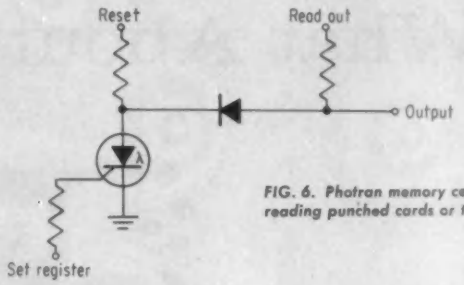


FIG. 6. Photran memory cell for reading punched cards or tape.

A circuit very similar in concept to Figure 5 can be used with the Photran for punched card or tape reading, see Figure 6. In this circuit, the Photran acts as both a light sensor and a memory cell in an input register. It produces a high level output capable of directly driving subsequent logic stages. The set register bus is held negative until the card or tape is to be read, and then the negative voltage is temporarily removed. The reduced bias allows the Photran to respond to light if present. This bus can then be returned to its negative level to prevent spurious readings. Read-in can be very fast (within 20 microsec). The register is read out by applying a positive pulse to the readout bus. A 1 (high voltage) will be produced at the output if the Photran was not triggered by light, or a 0 (low voltage) if it was. The register is reset by temporarily removing the voltage on the reset bus.

Two Other Solid State Logic Devices

Another solid state device now coming into practical use for logic will find some of its first applications in control systems—the multiple aperture ferrite core. Multiple aperture devices (MADs) can perform complete logical operations entirely by themselves, without the need for any other circuit elements like resistors or diodes. The characteristic of the ferrite also provides these MAD logic devices with an innate nonvolatile memory capability. In MADs, the shape of the ferrite core is the means by which the logic function is realized. Thus, an AND core looks very different from an OR core. Figure 7 shows some typical MAD logic elements identified by the logic functions they perform. Figure 8 shows how a typical integrated magnetic logic shift register can be made up of OR cores and wire only. The proper choice of turns ratios permits one core to drive a number of others, and even switch flux in a long chain of cores without any need for intervening amplifiers.

Only a little farther off are practical control applications of electroluminescent-photoconductive (EL-PC) switches. These switches couple an EL lamp closely to a PC cell. Light from an external source falling on the PC cell will lower the resistance in series with an ac voltage source and thus light the EL lamp. Light from the EL lamp will then maintain the PC cell in the low resistance state, and the device thus remembers the external light input. Because the external input can come from another EL lamp, complete logic circuits can be built up from the basic EL-PC AND circuit, see Figure 9. The EL lamp at the top will light only if all three EL lamps across the bottom are lighted. The output light could be used to trigger a Photran for control of sizable amounts of power.—Ed.



FIG. 7. Shape of ferrite multiple aperture core determines logic function.

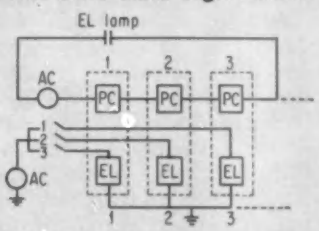


FIG. 9. Logic AND circuit based on EL-PC switches.

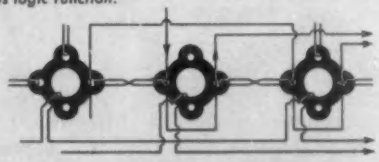
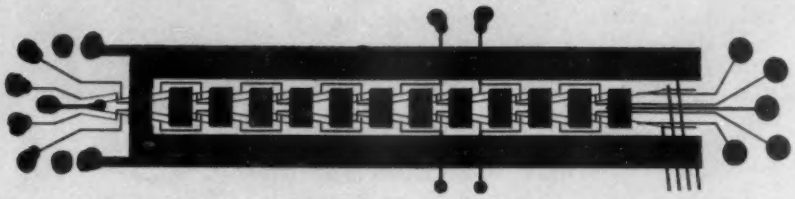


FIG. 8. Multiple aperture core shift register uses no other components.

What About Cryotronics?



Cryotrons with a gain-bandwidth of 10^9 sec^{-1} are on the brink of commercial application. These low temperature switching devices will probably first be used as large computer memories.

MARTIN L. COHEN, Arthur D. Little, Inc.

Cryotronic development has been primarily on a research basis to date, and has not yet reached the state where extensive systems-user experience can help in evaluating accomplishments. The largest existing cryotron circuit, containing 1,802 wire-wound cryotrons, was completed only four years ago. Subsequent efforts have been directed toward development of the film cryotron. Single cryotrons were produced and tested, and simple circuits such as oscillators, shift registers, and memory arrays have been made, the most complex of these containing less than 200 cryotrons. One such circuit, a shift register, is shown above. Circuits containing over 16,000 cryotrons are on the drawing board.

Tests and measurements have been made of the properties of superconducting films and circuits, and enough data have been gathered that cryotron characteristics, gain-bandwidth factors, and circuit behavior are reasonably well established. But little has been determined concerning reliability, life, manufacturing costs, or yield. For example, silicon monoxide has been an adequate insulation material in the laboratory, but the incidence of short circuits and crazing (a flaky disintegration with time) may make it unsatisfactory for commercial production. Glass and quartz have made convenient substrate materials so far, but experiments indicate that a more thermally conductive substrate, probably metal, is desirable. Development along these lines is just beginning; there are many fabrication techniques to be worked out.

However, the observed cryotron characteristics are highly desirable, and the engineering required to advance cryotron production from the laboratory to commercial production does not appear to be too difficult.

Cryotron switching

Functionally, the cryotron is similar to an electromagnetic relay. It is a superconductive switch whose output element (or gate) is switched from a superconducting state to a resistive (normal, nonsuperconducting) state by the magnetic field associated with the current in the output or control element. The major difference between relays and cryotrons is that a relay switches from almost zero resistance to almost infinite resistance, whereas a cryotron switches from zero resistance to some small finite resistance. Like a relay, the cryotron is active and nonlinear and can be used as an amplifier, oscillator, modulator, detector, and logic and memory element.

Physically, the cryotron is a thin film device. Earlier wire-wound cryotrons were supplanted by the thin film type because the film cryotron is many times faster, and is easier to produce than the wire-wound version. The structure, Figure 1, consists of films of lead and tin vacuum-deposited on a substrate. A shield or ground plane reduces circuit inductances, and some insulating material, usually silicon monoxide, is deposited where needed.

Cryotron circuits are usually operated in a current steering mode. In a circuit with two parallel paths, current from a constant current source will flow in the path of zero resistance and can be switched from one path to the other by quenching (making resistive) a cryotron gate in the path from which current is to be excluded. Energy is dissipated only during the switching process. Any current distribution is stable when all circuit resistances are removed. This behavior is used in all superconducting memories to store information by the presence, absence, or direction of persistent currents.

Speed of switching is governed by circuit time constants and by heat accumulation. The cryotron-gates switch from zero resistance to some small

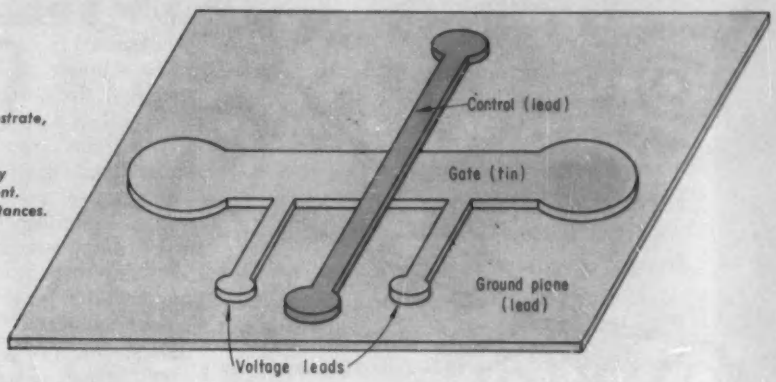


FIG. 1. Vacuum-deposited on a substrate, a lead tin cryotron consists of gate and control elements. The gate's resistance is increased by current flowing in the control element. Ground plane reduces circuit inductances.

finite resistance. This resistance (and therefore the cryotron circuit impedance level) is about 10^{-3} to 10^{-1} ohm, a very low impedance level by today's standards. For comparison, the resistance of one foot of #20 copper wire is 10^{-2} ohm. Because of the low impedance level, capacitances are usually negligible and circuit transients are governed by L/R time constants. A ground plane keeps circuit inductances at a low level, on the order of 10^{-12} to 10^{-10} henry. On the basis of control inductance and gate resistance, a gain-bandwidth figure of merit of about 10^{9} sec^{-1} has been computed for lead-tin cryotrons. Thus, unit gain and one nanosec time constants are possible. Circuit time constants are somewhat higher, due to stray inductance.

Heat accumulation also imposes a limit on switching speed. Although energy is dissipated only during a switching operation, heating is confined to the small gate areas. The resultant pulse power densities can cause an appreciable temperature rise and thus limit the repetition rate of circuit operations. But this heating problem is minimized in several ways. High thermal conductivity substrates carry heat from gate areas. The cryotrons can also be operated with a fixed control current bias, thus reducing the current to be switched by the gates and thereby reducing heating. A suitable bias also causes the cryotrons to operate in a higher gain region, increasing the gain-bandwidth figure of the cryotron by an order of magnitude. However, there are some objections to biased operation—it reduces the available output signal, requires more complex circuitry, and requires closer control of cryotron characteristics.

The low impedance levels that are inherent in cryotrons can be disadvantageous for input-output circuitry. Output voltages are small, sometimes under one millivolt, while drive currents are often large, from 0.5 to 1 amp. This is not too severe a limitation, however, as the difficulty of designing sense amplifiers for these small voltages is reduced by the relative lack of noise in cryotron circuitry, and the problem of supplying large drive currents is mitigated by the low inductance of the input circuits. The cost of input-output circuitry for a cryotron memory should be about the same as for any other memory of comparable speed.

Dissipating heat

Heat introduced into the refrigerator by leads is greater than that caused by switching—the heat produced per switching operation is on the order of 10^{-10} watt-sec, so that switching 100 cryotrons at a 10-Mc rate produces only about 0.1 watt of heat. Heat input from the leads depends on the temperature differential between the ends of the line, cross section of the lead, and heat produced in the leads by joule heating. A thin lead-in wire conducts only a small amount of heat, but produces large amounts of heat due to its electrical resistance. Optimum lead design is thus based on balancing heat conducted against heat produced, and depends on lead length and the magnitude of the input current.

Even with optimum leads, heat transfer stations are used at intermediate temperatures to keep heat input down to easily handled levels. More heat is introduced to a cryostat by an input lead starting at room temperature, 290 deg K, than by a lead starting at liquid nitrogen temperature, 80 deg K. And because low-temperature refrigeration is costly (at 3.4 deg K, 3 hp is required to dissipate a watt of heat), it pays to make the jump from room temperature to the cryotron operating temperature, 3.4 deg K, in several steps. When a lead goes directly from room temperature to a cryotron in one step, a heat load of about 42 milliwatts per amp must be removed at the low temperature end. This can be reduced to only 3 milliwatts per amp at the low temperature end by providing a heat-removing station at 80 deg K to remove a 40-milliwatt per amp load, and another station at 20 deg K to remove a 9-milliwatt load. Low temperature refrigerators are designed to provide the intermediate temperatures needed for such heat stationing.

In practice, somewhat larger heat loads than those indicated are encountered, since the optimum length-to-area ratio sometimes requires excessively

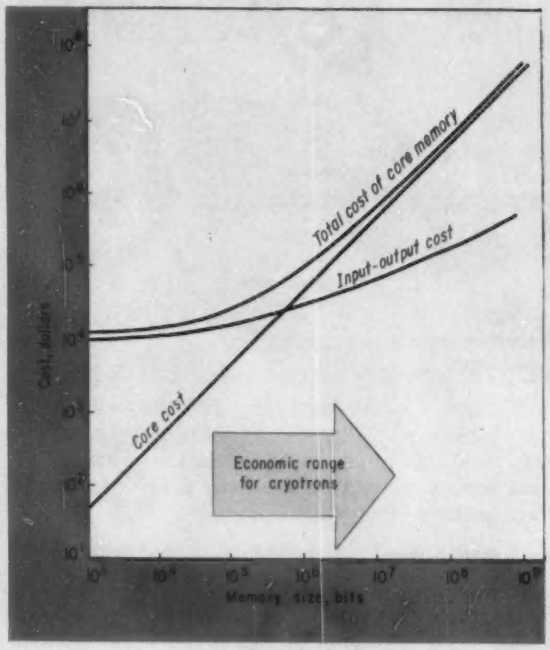


FIG. 2. Comparative costs of core and cryotron memories indicate range where cryotron memories are economically feasible.

fine wires or extremely long leads. A heat load of several watts might be encountered at the cryotron operating temperature, even when heat transfer stations are used.

Cryotron applications

All the numerous electronic functions obtainable from a nonlinear active element are obtainable from cryotrons, subject to the particular gain-bandwidth product, impedance, and power level limitations of cryotrons. Though conceivable, an all-cryotron computer presents certain problems for transmission of signals from memory to arithmetic units and back to memory at sufficiently high speed, because of the low impedance level of cryotron circuits.

A cryotron memory with transistor logic is a reasonable combination. The gain requirements of memory are low, making high speed obtainable. If cryotron tree switches are used for input decoding to reduce the number of devices needed, memory cycle time is largely determined by tree switch speeds. And because computer memories are the most compact, repetitive, and largest (in terms of number of components) part of the computer, the memory application is the most feasible. Finally, usability of cryotron memories is enhanced by the variety of memory types possible. Both random access and associative (content addressed), as well as destructive and nondestructive types are possible. Multiple address and internal transfer are also readily obtained in cryotron memories.

To estimate commercial feasibility of a cryotron memory, the cost of a core memory is compared with cost of a cryotron memory in Figure 2. For a core memory, core cost varies directly with memory size. The straightline core cost curve is based on an assumed core cost of $0.05 per wired core. Input-output equipment costs are both fixed and variable. Sense amplifiers are a fixed cost since one sense amplifier is required per bit of word length. In Figure 2, 100-bit words were assumed and sense amplifier cost was estimated at $100.00 each, and although not shown as a separate item, their cost would appear as a straight line across the graph at the 10^4 level. Cost of driver amplifiers per memory is variable. By assuming a two dimensional word selection memory, the number of drivers required is twice the square root of the number of words. Cost per driver is estimated at $100.00. Driver and sense amplifier costs are summed together and appear as *Input-output costs* in Figure 2. Thus, based on reasonable assumptions, input-output equipment is the largest part of the cost of core memories smaller than 10^6 bits. For larger memories, cores become the largest part of memory cost.

Cryotron memory costs, in comparison, are not economical for small memory applications because of the fixed cost of refrigeration. Memory costs should be less than $0.01 per bit. Only the range upward from about 10^5 bits should be considered. In the lower part of this range, 10^5 to 10^6 bits, cryotrons are economically competitive with any other memory of similar speed, because drive and sense costs are comparable. In the memory sizes where bit cost predominates, cryotrons offer not the lowest cost, but the lowest cost-to-speed ratio. However, the estimates for cryotrons can be expected to shift lower on the cost scale, because of additional developments now under way in cryotron memories.

Cryotronic developments

Cryogenic temperatures have been obtainable for over half a century, yet there has been resistance against the commercial use of these low temperatures. To some extent the attitude is justified, because reliable cryostats and closed-cycle refrigerators have been produced only recently. Because of current research and development, the availability of liquid helium refrigerators as reliable and compact as a household refrigerator can be anticipated.

Several companies are now at work on the engineering problems involved in constructing useful cryotron memories. In the next year pilot plant models with a capacity of several thousand bits will p.obably be built. These efforts will provide a sufficient basis for the design of larger commercially useful cryotron memories in the 10^5 to 10^6 bit range. This reduction from development to practice should occur within about three years.

Power transistors and silicon controlled rectifiers are now important as control system power modulators, amplifying information signals to drive actuators. This article compares the performance and application of these devices when they are operated both *on-off* as the output element in switching systems and continuously as power modulators in closed-loop systems. The rest of this section reports on solar cells, thermopiles, and thermoelectric devices as new control system elements. The second article discusses self-contained power supplies; the last article tells how to control the temperature of critical system components.

Power Control With Semiconductor Devices

B. MOKRYTZKI, R. MURRAY, R. PUTKOVICH, D. A. PISARCIK, and T. E. EBERT, Westinghouse Electric Corp.

The ability of some of the newer transistors to handle large amounts of power and the recent availability of silicon controlled rectifiers have made semiconductor devices important in the power control portion of automatic systems. Two types of power modulation functions are involved: the *on-off* switching of power in relay and logic systems, and the continuous modulation of power in equipment such as servo systems and adjustable speed drives.

Interest in transistor logic modules to replace electromechanical relays in the information handling portion of switching systems has caused a corresponding interest in solid state devices to replace output power relays. Both power transistors and controlled rectifiers are being used in power switching in the form of commercially available packages from manufacturers of transistor logic modules and in special configurations developed by individual control engineers. These devices generally take the place of single pole electromechanical relays and drive such loads as solenoid valves, motor starters, and clutches.

Transistors and controlled rectifiers are also suitable for use in continuous power amplifiers in which power output is some continuous function of the input signal. These units are rapidly replacing tube, magnetic, and rotating amplifiers in servo systems, welding control, ac and dc adjustable speed drives, power supplies, electric furnace control, etc.

The following material first examines the characteristics of power transistors and controlled rectifiers as elements in power control systems and then surveys the ways in which they can be used. Included in the latter are straight *on-off* switching circuits, high speed switching techniques in which essentially continuous amplification is achieved by pulse or phase modulation, conventional amplifiers, and converter circuits.

A LOOK AT DEVICE CHARACTERISTICS

Of interest here are those transistors designed to control large amounts of power either as class *A*, *B*, or *C* amplifiers or as switches. Key performance factors are input and output characteristics, saturation resistance, leakage current, thermal impedance, and gain. The familiar small signal parameters are of minor importance in such devices and will not be considered. An NPN silicon power transistor rated at 30 amp collector current demonstrates the most important characteristics.

The input characteristics for this unit with base-emitter voltage (V_{BE}) positive are shown in Figure 1A. In class *B* or *C* amplifiers and in switching applications the base-emitter diode

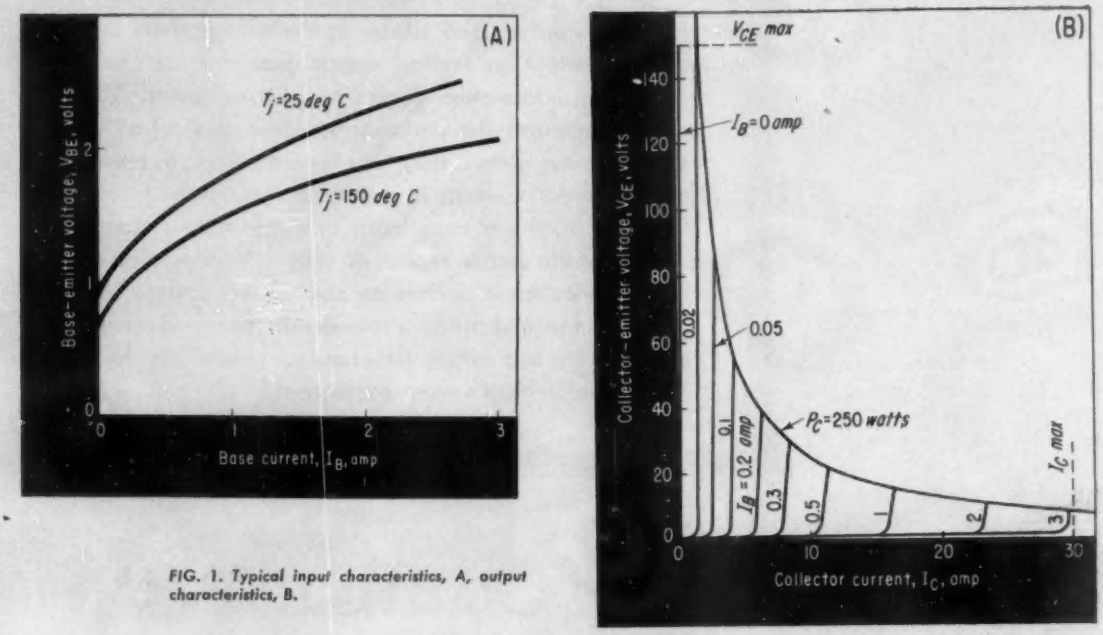


FIG. 1. Typical input characteristics, A, output characteristics, B.

is driven in the reverse direction during a portion of the cycle. In this case the reverse ratings and characteristics of the emitter junction must also be considered. For the example transistor, maximum values are a maximum base current (I_B max) of minus 25 milliamp at a V_{BE} max equal to minus 15 volts for a junction temperature (T_j) of 150 deg C.

Output characteristics for the 30-amp transistor are shown in Figure 1B. Here the entire area bounded by maximum voltage rating (V_{CE} max), maximum current rating (I_C max), and maximum collector dissipation (P_C max) is a useful operating region, provided thermal ratings are not exceeded. Careful attention should be given to the various manufacturers' ratings. Often voltage ratings are stated in terms of collector to base junction reverse biased and the emitter open-circuited (V_{CEO}) or in terms of collector to emitter with base shorted to emitter and collector junction reverse biased (V_{CEX}). These ratings place restrictions on the base biasing conditions and are therefore not applicable over the entire range of output characteristics. When in doubt use voltage rating collector to emitter at zero base current with collector junction reverse biased (V_{CEO}).

Saturation resistance is the slope of the collector characteristic under saturation conditions; i.e., with both collector and emitter junctions biased in the forward direction. It is achieved by overdriving the base to turn the transistor switch on. Switch conduction loss is proportional to saturation resistance. For the example transistor the maximum saturation resistance is 0.15 ohms at I_c equal to 20 amp.

Leakage current, I_{CEX}, flows during switch-off conditions, when both emitter and collector junctions are reverse biased, and produces blocking loss in the switch. For the 30-amp transistor I_{CEX} max is equal to minus 30 milliamp at maximum rated voltage and a junction temperature of 175 deg C.

Thermal impedance determines how much power can be dissipated in the device without exceeding the junction temperature limit of 100 deg C for germanium units and 175 deg C for silicon. The 30-amp transistor has a limiting thermal impedance of 0.45 deg C per watt.

Germanium power transistors have current ratings to 50 amp, BV_{CEO} ratings to 65 volts, and power dissipation to 30 watts at a case temperature of 70 deg C. Silicon power transistors have current ratings to 30 amp, BV_{CEO} ratings to 200 volts, and power dissipation ratings to 170 watts at a case temperature of 70 deg C. The high voltage and power ratings usually make silicon types preferable to germanium, particularly in military applications.

In most instances the manufacturer guarantees a minimum dc current gain in the range from 10 to 20 at a specified current value. However, a recently announced transistor features a minimum current gain of 400 at 10 amp, with BV_{CEO} ratings to 150 volts.

Controlled rectifiers

The most promising of the new semiconductor devices is the three-junction three-terminal device known as the silicon controlled rectifier. It will either absorb a high voltage and prevent the flow of current or breakover to a low voltage and allow load current to flow. Figure 2A shows these properties. The collector junction blocks the flow of current until a sufficiently high cathode to anode voltage differential of the polarity shown is reached. At this point an avalanche-type breakdown occurs, causing the device to go into a hyperconductive state with high forward current. To regain the forward blocking characteristic the current must decrease below a minimum holding cur-

SILICON CONTROLLED RECTIFIER

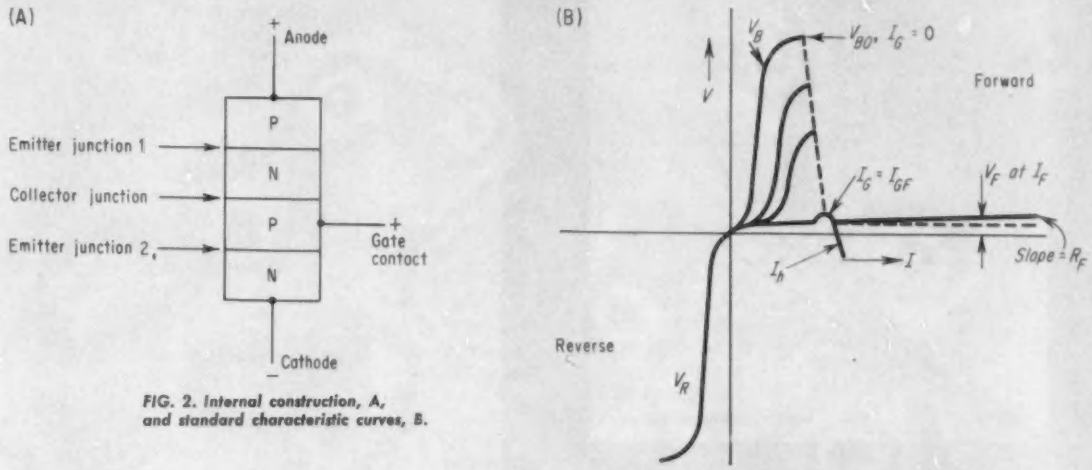


FIG. 2. Internal construction, A, and standard characteristic curves, B.

V_{BO} —Breakover voltage at zero base current

V_R —Rated reverse voltage at specified leakage current

V_B —Rated forward blocking voltage at specified leakage current

V_F —Forward voltage drop at specified current and junction temperature

R_F —Differential resistance of device in the on state

I_{GT} —Gate firing current

V_{GT} —Cathode-gate voltage necessary to drive I_{GT}

I_h —Minimum current through device to hold in on state

T on—Switch-on time to specified load current from initiation of turn-on pulse to 10 percent of initial blocking voltage

T off—Switch-off time from specified load current (including storage time) to 90 percent of final blocking voltage

rent value. The gate region also controls switching action. The critical anode voltage at which conduction occurs becomes progressively less as the gate current increases, until the device exhibits a voltage characteristic similar to that of a forward biased PN junction. Under reversed applied voltage the two junctions, emitters 1 and 2, exhibit the typical reverse voltage characteristics of a silicon rectifier. These properties are also apparent from the standard characteristic curves of Figure 2B.

Various methods have been adopted by the manufacturers for voltage classification. The units in any voltage class will absorb any forward voltage up to the specified voltage, while the ability to block voltage depends on gate circuit conditions. A few manufacturers require gate to cathode external resistance during the application of forward voltage at high temperatures. This resistance and/or a slight reverse bias during the blocking state shunts portions of various currents around the gate junctions, permitting higher blocking capability and more reliable operation. The most common practice is to specify a minimum forward voltage between the gate and cathode terminals that will not affect the blocking voltage. The system designer can select the proper resistor to clamp this voltage should leakage or magnetizing currents be flowing in the gate circuit during the forward blocking condition. When reverse voltage is applied the gate should be open-circuited or clamped, since the presence of gate firing current will cause an increase in reverse leakage with the possibility of destruction through thermal runaway.

The current carrying capability of a controlled rectifier is limited by the loss of control function at high operating temperatures. The junction temperature during operation depends on the total power dissipated in the device and on the thermal transfer characteristics from junction to ambient.

The power dissipated consists of blocking losses, control losses, and conduction losses. The losses during switching depend on the rate of load current rise during the transition from blocking voltage to the saturated on condition, and on the operating frequency. Both can be appreciable and may dictate the maximum operating conditions. Thermal transfer characteristics have been available for steady state conditions and are now available for transient conditions. The maximum average power losses versus current for various conduction angles, with consideration given to blocking, control, and switching losses, are shown in Figure 3. The dotted curves in Figure 3, determined from power losses and thermal transfer characteristics, show the maximum allowable case temperature as a function of current and conduction angle. At no time should the maximum rated junction temperature be exceeded. Should this occur, the anticipated blocking characteristic would be lost with possible deterioration or destruction.

For short time overloads, the current capacity of a controlled rectifier is limited by the power generated and the ability of the junctions to store this energy, since excessive temperature rise is destructive. A curve indicating the maximum nonrepetitive overload current for several time periods is supplied by most manufacturers for determining the necessary type of current limiting. Repetitive over-

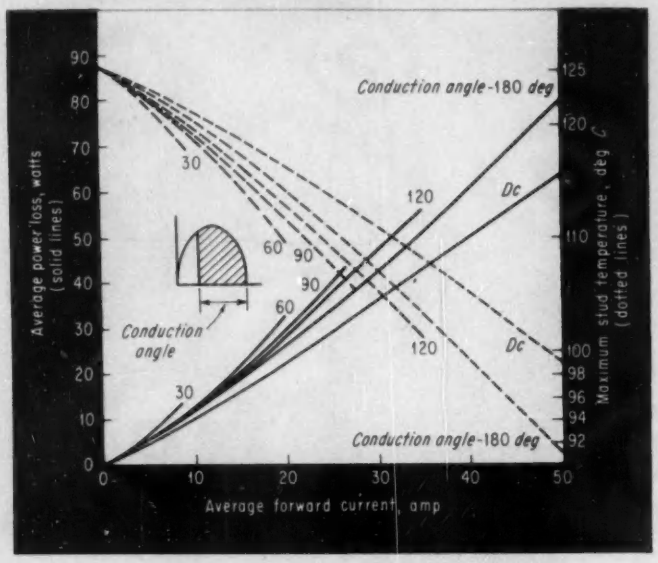


FIG. 3. Power loss and stud temperature as functions of forward current and conduction angle.

loads should be treated with caution.

Controlled rectifiers respond in the order of microseconds; however, both turn-on and turn-off characteristics are circuit dependent and any values published are only representative of the device measured in a particular circuit configuration. Turn-on time can be decreased by overdriving the gate. Turn-off time is that required to regain control after forward conduction. Control is regained by decreasing the current to a value below the holding current. In circuits where the current supplied to the load is not alternating or does not approach zero, an external means of decreasing the current is necessary to regain the forward blocking characteristic.

Available controlled rectifiers have current capacities ranging from a few milliamperes to 150 amp. The smaller devices up to 1 amp can be turned off by applying reverse gate power with gain, but at present it is not feasible to turn off the higher power units through reverse gate control. Controlled rectifiers with current ratings approaching those of presently available silicon rectifiers are in development; this will extend the power range of equipment utilizing these devices into the megawatt range.

Maximum voltage capacity is now 600 volts in the 5 amp and less current range. Higher current rating devices are limited to a maximum blocking voltage of 400 volts.

Comparing the two devices

The major differences between the transistor and controlled rectifier are:

- The transistor requires a continuout signal to initiate and maintain conduction; the controlled rectifier requires only a short duration pulse to initiate conduction.
- The transistor can be switched off by reversing the polarity of the control signal and can be controlled at any intermediate position by supplying proportional amounts of base power; the controlled rectifier requires that load current be reduced to nearly zero before conduction ceases.
- Maximum load current in a transistor depends on base current and gain; in controlled rectifiers load current is independent of base current.
- A controlled rectifier blocks reverse current flow; transistors can pass relatively large reverse currents.

The devices are not interchangeable in circuits, and careful consideration must be given to the selection problem.

The transistor has been in use for some time, while the controlled rectifier is relatively new. This gives the transistor several advantages that may die out with time. System designers are familiar with transistors, and vast amounts of performance and application data are readily accessible. In addition, there is a much wider variety of power transistors on the market. Many are intended primarily for use in linear amplifiers where power gain, linearity, and noise characteristics have been optimized, while others are mainly for switching applications where on and off power losses and switching times have received the most attention. Controlled rectifiers have not yet reached this stage of flexibility.

One more advantage of transistors not to be taken lightly is the maximum operating temperature. A few silicon transistors are available with operating temperatures up to 200 deg C. The smaller current (less than 5 amp) controlled rectifiers have operating junction temperatures of 150 deg C, but the higher current devices have maximums of 125 or 100 deg C. This is an important factor when considering a device for operation in high temperature conditions.

The controlled rectifier does have advantages over the transistor. One of the most important is the rectifier's inherent ability to control much higher power per unit junction area. Another is the fast turn-on time of controlled rectifiers, as low as 0.6 microsec from blocking rated voltage to conduction of rated currents as high as 50 amp. This is much faster than a transistor. And since the turn-off times for both devices are nearly equivalent, total switching time of the controlled rectifier is much shorter.

The dynamic resistance of the controlled rectifier in the high conduction region is also much lower than that of a transistor, leading to lower power losses in the on condition. This effect, combined with fast switching times, results in improved circuit performance. Controlled rectifier circuit efficiencies approaching 99 per cent are not uncommon.

In the substitution for electromechanical switches, and in the inverter field in particular, the controlled rectifier has permitted advances unattainable with transistors. This trend will undoubtedly continue as more experience is gained.

Application guides

Power transistors, like all semiconductor devices, are subject to damage from abnormally high voltage. It may be necessary to employ zener diodes, selenium transient suppressors, or ca-

pacitors in the circuit if voltage transients exceed the maximum voltage rating of the device.

Careful attention must be given to heat sink design so that the maximum rated junction temperature of a transistor is not exceeded. If overloads are expected, the normal steady state junction temperature should be sufficiently below the maximum rated value to allow for the additional temperature excursion. Transistor thermal capacity governs the magnitude and duration of the permissible overload.

In switching applications, when overload surges of collector current are anticipated, sufficient base current must be provided for the transistor to remain in saturation during the surge.

The controlled rectifier is subject to similar transient and overload problems. Here simple thermal overload trip devices provide adequate protection during moderate overloads, but special care must be taken against high overloads such as direct shorts. High speed fuses can be selected based on the rectifier's I^2t rating and on steady state circuit requirements. In particular, the rate of current rise must be limited during the transition from blocking to conduction, and the maximum surge current must be limited depending on the magnitude of the voltage to be switched. Conventional overvoltage protection techniques such as RC networks, nonlinear resistors, and the newer selenium voltage suppressors appear to be adequate for most transients, but caution must be taken where there is a possibility of a high speed low energy transient.

Voltage transients can cause another problem. When the rate of rise of anode voltage exceeds a certain maximum, a controlled rectifier can turn on without a gate signal, even at anode voltages below critical. The junctions contain capacitance, and the fast rising voltage causes a current to flow similar to charging a capacitor. This current acts like a gate control current and can initiate switching action. Various solutions are possible, including adding capacitors and reverse biasing the gate circuit during the application of the anode voltage, but all add complexity.

Additional current capacity for controlled rectifiers can be achieved by parallel operation. Factory-matched cells for this application are available by special order. Although this is a desirable approach, the cost of replacing many paralleled units is high. The units must be matched at various current levels to ensure equal current distribution over the complete operating range. In high frequency applications, consideration must be given to the dynamic switching region, since unbalance in current build-up in this region can be detrimental.

The best way to force proper current balance is to use balancing reactors, Figure 4. Since the currents from the two cells pass through a core in opposite directions, any unbalance between the two currents will induce a correcting voltage.

It is also necessary to provide sufficient gate drive to ensure firing all units connected in parallel. Isolated gate circuits are desirable, but if the units are fired from a single source the source must be stiff enough to permit insertion of resistance in series with the gate leads to swamp out impedance variations.

For high voltage applications, controlled rectifiers can be connected in series. Again, differences will exist in leakage currents, turn-on characteristics, recovery times, and junction capacitances, and a method of providing uniform voltage distribution is generally required. Recovery time and junction capacity are especially important when a large number of cells are in series, and both shunt resistor and capacitor dividers may be necessary. The optimum value of shunt capacitance is about 100 times the junction capacity.

Particular care must be given to electrical isolation of the gate circuits. To ensure uniform firing, it is mandatory to supply four or five times the maximum current required to switch. This minimizes the possibility of excessive voltage build-up across one or more of the series string, initiating switching as a two terminal device. Gate signal rise should be as rapid as possible. Square wave activated magnetic circuits driving the units from multiple winding pulse transformers are ideal for this.

USING THE DEVICES IN POWER CONTROL CIRCUITS

The simplest application of a transistor or controlled rectifier in a power control system is as a switch, replacing a relay or contactor. Because semiconductor devices employ rectifying junctions, they normally can control current in one direction only and are basically spst switches.

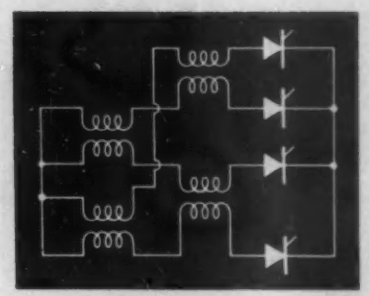


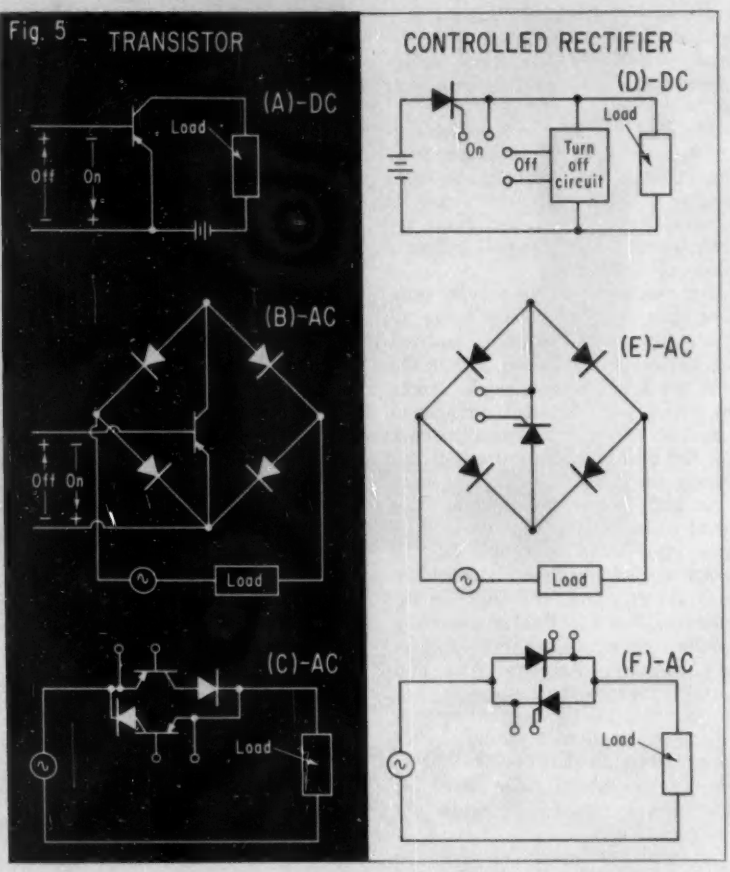
FIG. 4. Reactor current balancing in parallel rectifier circuit.

Several basic circuits that will fulfill the requirements of most switch or relay applications are shown in Figure 5. The transistor dc switch is turned on and off by applying a drive signal having the indicated polarities. Current and voltage required at the base depend on transistor characteristics and will vary widely for transistors of various power ratings. Typical values for current gain vary from several hundred at low load currents to 10 or 15 at high currents. The voltage required at the base is about 1 or 2 volts. To reduce leakage current during the blocking condition it is preferable to apply a reverse voltage of at least a few tenths of a volt to the base.

Ac transistor switches can be constructed as shown in Figures 5B and 5C. In Fgure 5B a rectifier bridge converts ac to dc so that a single transistor controls both half-cycles of the ac wave. In Figure 5C two transistors are used, with each transistor handling one half-cycle. Here, rectifiers are placed in series with each transistor to prevent reverse current when the switch is off.

The basic transistor circuit configurations can be used with a controlled rectifier, but additional circuitry is required because the device cannot be switched off with its base or control circuit. Basic turn-off circuits are described later.

In the controlled rectifier dc switch of Figure 5D a single pulse on the control lead will start conduction, after which it is no longer necessary to maintain the control signal. Unlike the transistor, the controlled rectifier's load current does not depend on the presence or magnitude of the base signal. Typical values of control current and voltage required to initiate conduction vary from 0.5 to 50 milliamp at 0.25 to 4 volts. The controlled rectifier switch is turned off



by supplying a signal to the turn-off circuit, which then must reduce the current through the switch to zero long enough for the device to regain its nonconducting state.

Again, it is necessary to utilize either a bridge rectifier or two controlled rectifiers to switch ac. In the ac circuits of Figures 5E and 5F, the control signal must be maintained on the base during the entire period of conduction, otherwise the switch will turn off at the end of each half-cycle. Another approach is to apply a turn-on signal at the beginning of each half-cycle of current. A turn-off circuit is not required.

Turn-off circuits

Where turn-off circuits are required with controlled rectifiers, one of the basic types shown in Figure 6 will usually suffice. The first is the series turn-off circuit where an impedance connected in series with the load causes the current to be sufficiently reduced or reversed. Figure 6A is an example where the values of R, L, and C are selected to yield an underdamped circuit. The oscillatory nature of the underdamped circuit causes the current to attempt to reverse, thereby turning off the controlled rectifier. A parallel path must be provided around the capacitor to allow it to discharge and restore the circuit to its original uncharged condition. This type of circuit has limited usefulness in relay-type circuits, but is useful in regulator and inverter applications.

The second type, Figure 6B, includes those circuits that momentarily divert the current from the controlled rectifier to a parallel path, while simultaneously reversing the voltage across the device. Assume that SCR1 has been turned on and load current flows through R_L. Capacitor C will charge to the value of the supply voltage with the indicated polarity. To turn off SCR1, SCR2 is turned on, allowing C to discharge through SCR2 and R_L, and to supply reverse voltage to SCR1. SCR2 continues to conduct until SCR1 is to be turned on again. If resistor R_s is much larger than R_L, SCR2 can be a lower rated device than SCR1. If both R_s and R_L are high power loads, the circuit behaves like a two-position relay, turning one load on when the other turns off.

The third basic type of turn-off circuit, Figure 6C, parallels the load. For turn-off, the shunt circuit must provide a voltage and current tending to oppose the source. When SCR1 is turned on, capacitor C charges to a value greater than the source voltage through inductance L and rectifier D. Current flows through SCR1 and the load until SCR2 is turned on. At this time the higher voltage of C places a reverse voltage on SCR1, turning it off. Since SCR2 conducts capacitor current only, its average current rating can be much less than that of SCR1.

The selection of the preferred type of switching circuit and turn-off circuit requires accurate specification of load type, power supply characteristics, duty cycle, and the relative importance of size, weight, cost, and reliability. Since no standard circuit designs now exist that can satisfy the entire range of actual requirements, it is desirable to optimize circuit design so that the full capabilities of the semiconductor switch are realized.

One thing to remember is that semiconductor switches never completely open or close a circuit. When open, switch resistance is between several kilohms and several megohms, depending on the device; when closed, switch resistance is about 0.01 ohms for high power devices and several ohms for low power units.

Continuous switching amplifiers

If the switching circuits discussed in the previous section are turned on and off at a high rate and if the ratio of on time to off time is proportional to the magnitude of the input signal, then the average output of the circuits will also be proportional to input signal. In this way continuous power amplification is achieved. Two techniques are available for controlling the ratio of on time to off time: pulse modulation and phase commutation.

CONTROLLED RECTIFIER TURN-OFF CIRCUITS

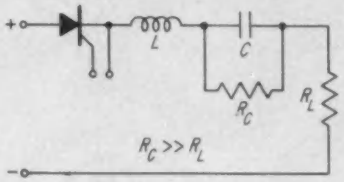


Fig. 6(A) With underdamped RLC

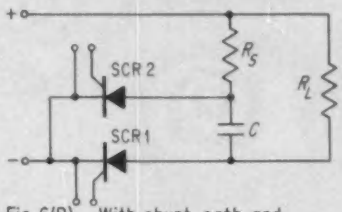


Fig. 6(B) With shunt path and turn-off capacitor

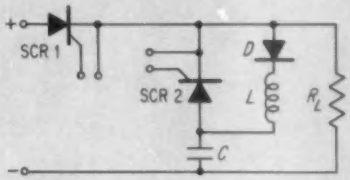


Fig. 6(C) With resonant charging shunt circuit

Pulse modulation

There are two approaches to controlling the output of semiconductor pulse modulators or choppers. In one the pulse repetition rate is kept constant and the conduction time per cycle or pulse width is varied; in the other conduction time is maintained constant and repetition rate is varied. In general, both approaches are applicable to the dc semiconductor switching circuits in Figure 5. Cycling rates vary from several cycles to 20 kc.

A high cycling or carrier rate is generally desired in both transistor and controlled rectifier choppers. This yields a higher effective speed of response and reduces filtering requirements for achieving a smoothed output. But each cycle of operation is a more or less dissipative process, hence, a high cycling rate is detrimental because it results in high dissipation. The dissipation is of two types. Part is within the active element and results in heating and ultimate derating of the device, and part, although external to the semiconductor, results in reduced efficiency. A compromise must be obtained, balancing a high cycling rate against low losses.

Superficially the transistor chopper is relatively simple, since all control is accomplished by the presence or absence of a gate signal. Actually, the process is more involved. While losses are low in both the on state and off state, in cycling between the two states a region of relatively high dissipation must be traversed. Switching time must be minimized to minimize this dissipation. Turn-on time can be reduced by applying the base drive rapidly, while turn-off recovery time can be reduced by using a reverse base voltage to extract the surplus carriers rapidly via a base sweep-out current. The ultimate switching rate, determined by the internal characteristics of the unit, will fix a maximum cycling frequency for a given power output.

In controlled rectifier choppers the turn-off time is the prime switching parameter, setting the maximum cycling rate. Although ultra fast in turn-on, the units do experience significant heating during reverse recovery. In the shunt capacitor turn-off mechanisms of Figures 6B and 6C this occurs during the short period after application of the capacitor voltage, when high recovery current is accompanied by finite voltages. The capacitor charging process is another loss source. The resistive charging circuit of Figure 6B is simple but inefficient, while the resonant charging technique of Figure 6C is efficient and produces higher capacitor voltage for better circuit utilization. The losses in the latter circuit are lower than in the resistive one, but in either case the energy involved is low for cycling rates near 100 cps. For rates higher than several kilocycles the charging-switching loss becomes significant regardless of the charging mode. Load has little effect on turn-off time.

Some differences should be emphasized when choosing between transistor and controlled rectifier choppers. When subjected to high transient voltages the controlled rectifier merely reverts to the conducting state, and thus must be provided with a peak voltage margin as protection against spurious or erroneous outputs rather than against device destruction. Transistors, on the other hand, break down with a constant voltage, high dissipation characteristic, and can be permanently damaged by such a breakdown even if it exists momentarily. However, the transistor is not required to sustain a reverse voltage as is the controlled rectifier in its version of the chopper. The controlled rectifier is sensitive to overcurrent, but is less susceptible to damage than the transistor, which is a drive limited current source. To accommodate overcurrents the transistor must be overdriven.

Choppers operate best in the cycling range from 100 cps to several kilocycles. The maximum practical limit for controlled rectifiers is roughly 20 kc. Higher frequencies are attainable with transistors, but only at lower power levels. The transistor chopper is more easily and reliably controlled, but the controlled rectifier version is more practical above power levels of several kilowatts.

Phase commutation

By adjusting the timing of a trigger signal in ac systems, the actual conduction period of a semiconductor system can be varied from its full allowed value to zero. The related method of current transfer is known as phase commutation and, at first glance, seems identical to modulating the width of a half-cycle ac pulse. This is very nearly true for a resistive load, but not for an inductive load such as the field of a rotating machine or for an active load such as the armature of a dc motor. Although it is possible to simulate controlled rectifiers using a transistor in series with a diode, transistor phase commutation is not worth discussing further.

Figure 7A shows a typical phase commutated rectifier; a single phase full wave bridge. The bridge consists of four switches fired in pairs on alternate half-cycles, permitting the conduction shown by the waveforms. For a resistive load the instantaneous output current and voltage waveforms are qualitatively identical. But for anything other than a resistive load the average output for a given phase angle α departs from this identity. For a highly inductive load the output current is constant, Figure 7D, carried by two different pairs of units on opposite

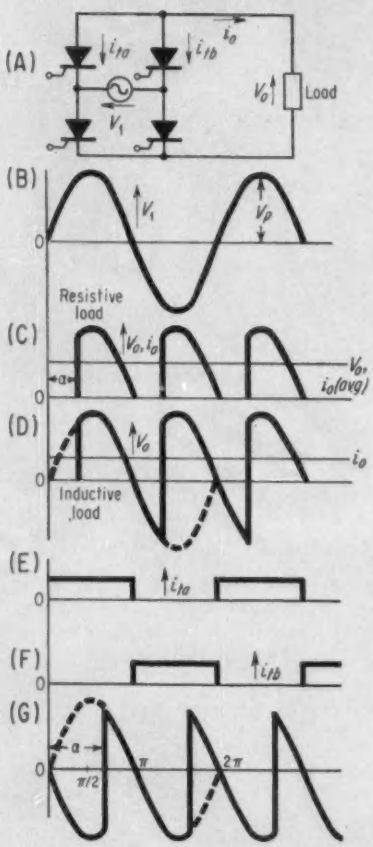


FIG. 7. The basic converter circuit and characteristic waveforms.

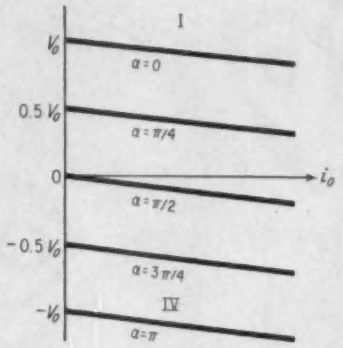


FIG. 8. Converter output characteristics.

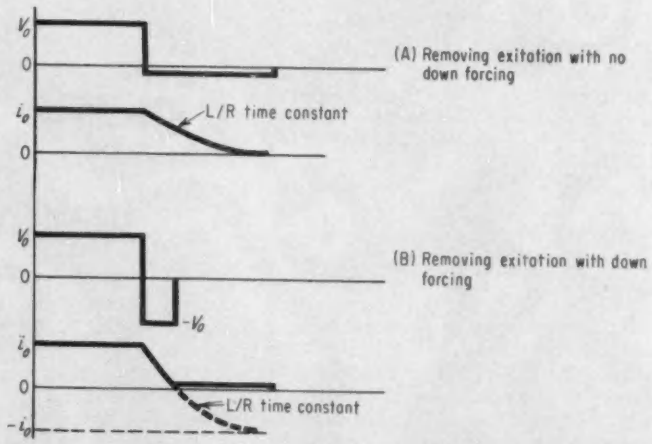


FIG. 9. Converter transients with and without down forcing.

half-cycles, Figures 7E and 7F. Output current level is set by average output voltage, given by difference between the two areas above and below the axis of Figure 7D. For $\alpha = \pi/2$ the areas above and below the axis are equal and output current is zero.

When α is retarded beyond $\pi/2$ the average output voltage assumes a negative sense. But since the current retains its original polarity the process involves the reversal of power flow and is defined as inverter operation. This is in contrast to the condition for $\alpha \leqq \pi/2$, defined as rectifier operation. The output characteristics for the converter, Figure 8, are shown existing in two quadrants. Quadrant I is the normal operating region for most rectifiers. But quadrant IV operation is unattainable with magnetic amplifiers and offers distinct advantages.

Assume that current flows in the load and the converter is operating as a rectifier. Removing excitation produces a transient, Figure 9. The firing angle is set at $\pi/2$, output voltage is virtually zero, and load current drops according to load time constant L/R. Using the properties of controlled rectifier converters, load current can be rapidly decreased if the firing angle is retarded beyond $\pi/2$, ideally to π. Note that the current is forced to zero as load voltage swings to its full negative or inverter value of $-V_o$ and the energy of the load inductor is depleted in a constant voltage discharge. For a passive load the action is valid for transients and the load voltage reverts to zero once current flow has ceased. There are two principal advantages to a converter with forcing: 1) up and down transients can be made symmetrical, and 2) the system is inherently faster.

Now consider the control of an active load, such as the armature of a dc motor. Figure 8 shows that regeneration is impossible with a simple converter since its operation is restricted to two quadrants. The significance of this is similar to the case of a converter without down forcing. Thus, a motor can be accelerated rapidly by applying excess voltage, but once converter voltage drops below the counter emf the converter is blocked and loses control. The motor coasts down in speed according to its losses and loading. The net result is dissimiliar up and down transients and a limited speed of response.

A more suitable motor drive made up of two simple converters connected in parallel opposition is shown in Figure 10. One unit operates as a rectifier with $\alpha_1 \leqq \pi/2$ and the other as an inverter with $\alpha_2 \geqq \pi/2$. The relative firing angles of the two units are constrained such that $V_{o1} \leqq V_{o2}$, which means that the net average out-

DUAL CONVERTER FOR DC MOTOR CONTROL

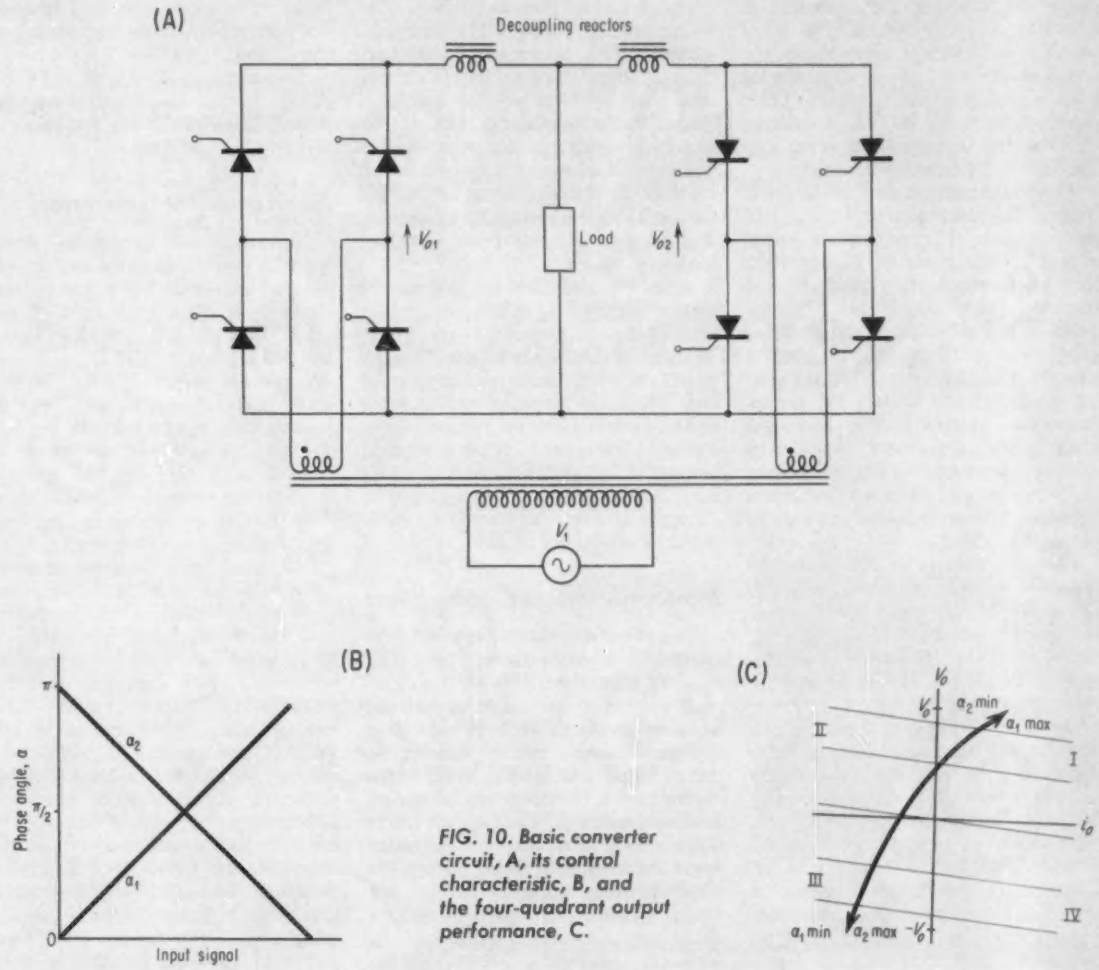


FIG. 10. Basic converter circuit, A, its control characteristic, B, and the four-quadrant output performance, C.

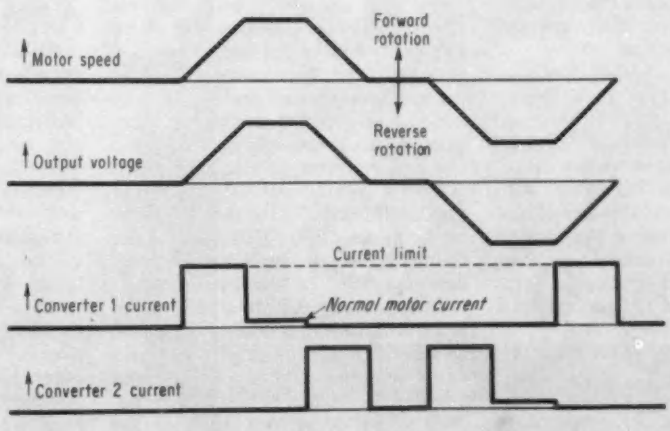


FIG. 11. Dual converter transients with motor load.

put voltage of a converter operating as an inverter is greater than the net output of its opposing unit operating as a rectifier. This is necessary to avoid placing direct voltage on both the decoupling reactors, since they cannot limit circulating dc currents. Their prime duty is to inhibit circulating currents due to instantaneous ac voltage differences between converters.

These conditions are achieved if the control characteristics of Figure 10B are provided. The net result is the output characteristic of Figure 10C. Here all four operating quadrants are available. Quadrants I and II correspond to forward rotation of the motor and quadrants III and IV to reversed rotation. Similarly, I and III are driving quadrants and II and IV are regenerating quadrants. The operating characteristics are almost identical to those of a rotating dc generator, Figure 11. Some device is assumed that limits the normally high transient currents to reasonable values.

These techniques are not limited to single phase systems, and generally, polyphase circuits using conventional rectifiers can be duplicated with controlled rectifiers. Improved performance often results. For example, the low dynamic impedance of a motor fed by a single phase converter might produce high ripple currents. A three phase converter presents lower ripple voltages and a higher, more easily filtered ripple frequency.

There are two popular modifications of these basic converter circuits. One is the cycloconverter—in essence a sinusoidally controlled dual converter. It can convert half-cycle segments of a relatively high frequency ac input into a low frequency ac output. The resulting waveform is a reasonably good sine wave if the input frequency is at least an order of magnitude higher than the desired output.

Another modification of the basic converter is the single phase bridge converter using two conventional and two controlled rectifiers. Although cheaper and simpler than the circuit of Figure 7, it performs equally well as a rectifier. However, the unit cannot act as an inverter since the vertical combination of a conducting controlled rectifier and a diode clamps the negative output of the converter to virtually zero.

Ac to ac phase control

If the principles of phase control are applied to the ac switches of Figure 5, it is possible to control ac equipment. This effectively chops out portions of a sine wave to produce a reduced effective voltage. The technique is useful in a variety of applications such as lamp dimming, motor control, and welding. One popular use is in induction motor starting. Normal high inrush currents can be prevented by starting the motor with the controlled rectifiers at retarded firing angles and advancing them as rapidly as possible according to a signal from a current sensing circuit.

All of the controlled rectifier circuits can be triggered by active magnetic or semiconductor elements either individually or in combination. Trigger pulses are synchronous and asynchronous. Magnetic amplifier synchronous pulse generators can be used to trigger controlled rectifiers in phase controlled converters, ac switches, and in choppers. Asynchronous pulses are used in choppers and can be formed by oscillators or relaxation circuits.

Semiconductor servoamplifiers

The power amplifiers described here are usually limited in gain so that they must be augmented by fast, high gain preamplifiers for use in servo systems. Stability problems such as zero drift and gain changes can be handled in the preamplifiers, leaving band width as the prime consideration in power amplifier selection. Here a key factor is the symmetry of amplifier response. Apart from merely being faster, an amplifier with symmetrical up and down performance avoids certain closed-loop stability problems. In optimum response on-off servos, for example, better performance is needed that has been attained by existing devices such as magnetic amplifiers. Present amplifiers lacking down-forcing ability can be duplicated by choppers and the two-controlled-rectifier bridge. But optimum performance can only be achieved if the on-off operation is accompanied by the symmetrical response of the single converter in field control or inductive load applications, or the dual converter for dc motor drives. This performance cannot be simply duplicated by magnetic amplifiers or transistor devices.

In ac systems the ultimate speed of a semiconductor amplifier is limited to a fraction of a half-cycle dead-time response. Speed can only be increased by using a higher ac excitation frequency. In dc systems such as the chopper, the limit is again a dead-time response, effectively a fraction of a cycling interval. Thus if down forcing is not a requisite, the high frequency chopper is potentially the fastest power amplifier.

Conventional class A, B, and C transistor power amplifiers have been widely discussed in the literature and will not be covered here.

Semiconductor converters

Semiconductor switching devices used in power converter circuits offer another important tool to control engineers. Four basic types of conversion are possible: ac to dc, dc to ac, ac to ac frequency changer, and dc to dc voltage transformation. The first, ac to dc or rectification, has already been discussed. Of the remaining three, dc to ac conversion is perhaps most important since the last two generally include the conversion of dc to ac. Both transistors and controlled rectifiers can be used. Frequencies up to 20 kc have been obtained at power levels in excess of 500 watts with both.

In control systems, power conversion circuits may find application in the control loop itself or as auxiliary equipment. For example, where ac motor speed is to be controlled a variable frequency inverter can be used to drive an induction motor. As auxiliary equipment, a battery driven converter can serve as an emergency power supply. If higher frequency ac is needed to improve system response a converter can be designed to change 60 cps to any higher frequency within the audio frequency spectrum. Also, by using a converter having a dc input and rectifying its ac output, a dc transformer is obtained.

A look ahead

While silicon power transistors are expected to decrease materially in price in the next five years, it is not anticipated that their current and voltage ratings will be significantly increased. In contrast, silicon controlled rectifiers are expected to increase considerably in both current and voltage ratings, and to decrease in cost per volt-ampere of rating. Future developments in molecular electronics may make it possible to combine low level logic circuitry with high power switch circuitry in a single unit. It may even become technically and economically feasible to duplicate multiple pole or multiple contact arrangements in a single semiconductor structure.

THE GIST: Silicon photovoltaic cells and thermocouples can convert solar energy and heat into electrical energy. Both means of energy conversion are potential self-contained power supplies for control and data handling systems. Prime applications have been in satellites and other inaccessible military systems, but isolated examples of industrial use already exist. Device characteristics such as capacity, efficiency, and weight, and system considerations are covered to acquaint control engineers with this new solution to the remote power supply problem.

Solid State Power Supplies

GEORGE HUNRATH
U.S. Army Signal Research and Development Lab.

The silicon photovoltaic cell, or solar cell, used in a number of satellite power supplies consists of a 1 by 2 cm rectangular wafer of N-type single crystal silicon. The active cell surface is a layer of P-type silicon created by boron diffusion to a depth of about 1 micron. Ohmic contacts are added to one edge of the active surface and to the entire back of the cell, Figure 1.

When exposed to the sun, photons of light energy are absorbed within 10^{-4} cm of the active surface. The high energy photons split off electrons from their normal position in the crystal lattice, leaving vacancies and thereby creating electron hole pairs. The transition region from P to N-type silicon provides an electric field gradient, attracting electrons into the N region and holes into the P region. The cell is equivalent to a source of energy in parallel with a forward-biased diode.

Solar energy availability

The operation of a solar cell power supply depends on the availability of solar energy. This varies greatly over the surface of the Earth depending on atmospheric conditions, seasons, and geographical location. Information on the mean percentage of possible sunshine on a monthly and annual basis for various locations in the United States can be obtained from the weather bureau and other sources (Refs. 1, 2, and 3).

The spectral distribution of the sun's energy reaching the Earth is modified by absorption by atmospheric gases, water vapor, and dust. This affects the optical path length through the atmosphere, causing it to vary with time of day and season. Under ideal conditions with the sun at zenith, available solar energy on the Earth reaches a maximum of 1.5 cal/cm²/min, equivalent to 1,000 watts/m² with the receiver at normal incidence. In outer space available solar energy is based on the solar constant of 2.00 cal/cm²/min (at Earth's mean distance from

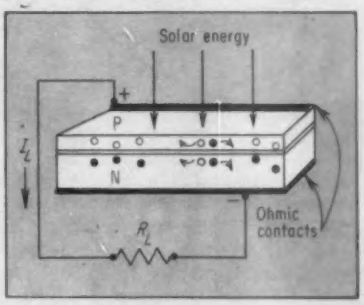


FIG. 1. Silicon photovoltaic cell.

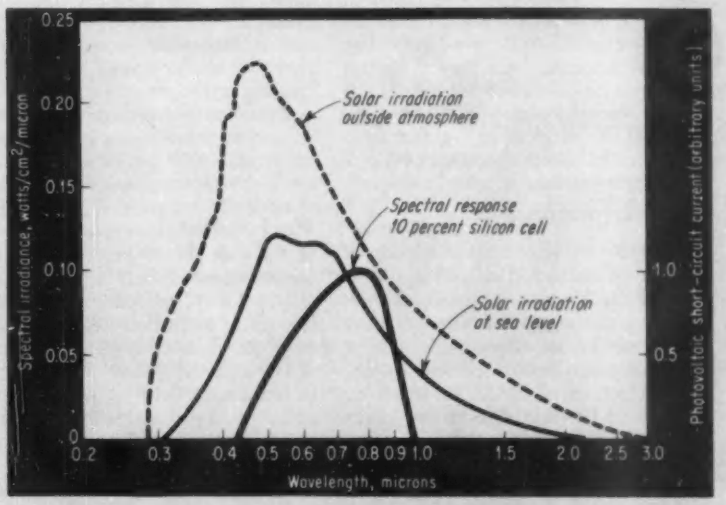


FIG. 2. Spectral energy distribution of typical silicon cell and of solar energy on Earth and in space.

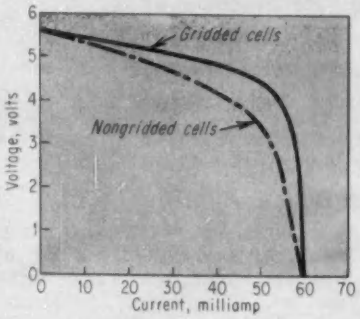


FIG. 3. Current-voltage characteristic for ten 1 by 2 cm cells at 38 deg C with 2 cal/cm²/min light intensity.

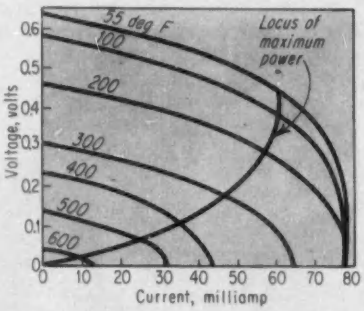


FIG. 5. Temperature effect on current-voltage characteristics for light intensity of 2 cal/cm²/min.

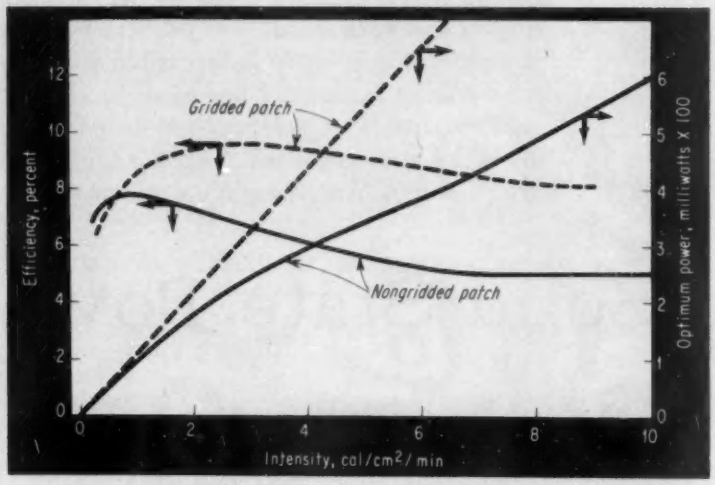


FIG. 4. Efficiency and power output vs light intensity for ten 1 by 2 cm cells at 38 deg C.

sun), equivalent to 1,400 watts/m² with the receiver normal.

Comparing the solar spectral energy distribution curve for outer space with that for the Earth's surface, Figure 2, reveals a peak shift from 0.45 micron for space to 0.5 to 0.7 for Earth. The spectral response of a typical silicon cell peaks at 0.7 to 0.9 microns. Thus conversion efficiency of a cell in space will not be as great as for the same cell on the Earth's surface, necessitating a correction factor.

Cell performance characteristics

The recent addition of grid-type contacts to the active surface of cells (in place of the type of ohmic contact in Figure 1) has improved efficiency by providing shorter current paths. This effectively reduces the series resistance of the thin P layer and yields a more rectangular current-voltage characteristic, Figure 3. Under open circuit conditions the total generated current is the diode current. When load resistance is less than 1 ohm, approximating a short circuit, the voltage across the diode junction is very low and total current generated can be assumed to be in the load. Maximum power transfer occurs when load impedance equals cell impedance. Cell impedance in turn, varies with cell area, light intensity, temperature, and angle of incidence.

Cell power output closely follows the cosine law if the load is adjusted for maximum power at the various angles. But if the load is adjusted for maximum power at normal incidence and is held fixed, power output departs from the cosine law with increasing angle.

Power output per unit cell area increases with increasing light intensity, while efficiency peaks at about 0.75 cal/cm²/min for a nongridded cell and at about 2 for a gridded cell, Figure 4. Theoretical efficiencies of silicon cells in the order of 20 percent have been calculated. Actual cells with efficiencies of 9 to 12 percent are available in reasonable quantities (cell at 25 deg C and equivalent sea level solar intensity of 100 milliwatts/cm²). Losses are due to low energy level of some photons, reflection, shunt and series impedance, recombination of electron-hole pairs, and contact resistance.

The cells are temperature dependent and lose power with increasing temperature at a rate of 0.5 percent per deg C. The half-power point with 25 deg C as a reference occurs at 125 deg C. Cell voltage also decreases with increasing temperature at a rate of 2 millivolts per deg C. Figure 5 shows these temperature effects and includes the locus of maximum power transfer.

System considerations

Where power is required during the dark period of a satellite orbit—or at night or under overcast skies on the ground—sealed nickel cadmium storage batteries are used. They present a fairly constant voltage load to the solar power supply, improving voltage regulation, and can also furnish peak load demands. An early experiment to explore the possibility of such a system for ground use was conducted by Bell Telephone. While found to be technically feasible, system cost was too high. Direct coupling of a solar power supply to a load without a storage system will find few applications.

The design of a satellite solar power supply requires knowledge of the type of orbit, peak and average power demands, and duty cycle. Then calculating the watt-hours removed from the storage battery per orbit makes it possible to determine the capacity of the solar cell array to maintain the proper power balance. System design factors include: available solar energy, spectral

SATELLITE POWER SUPPLIES

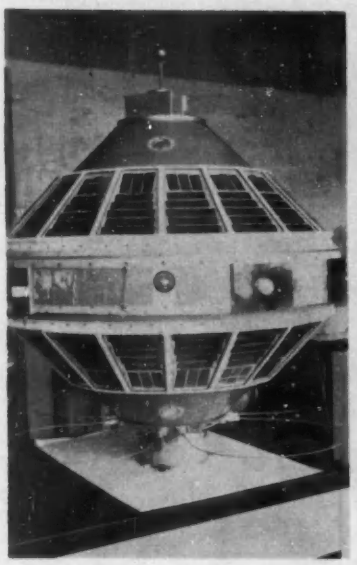


FIG. 6A. Explorer.

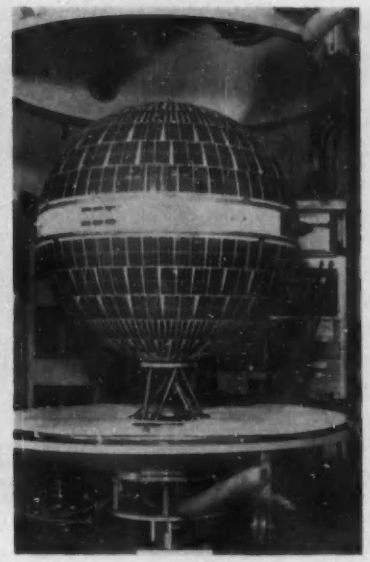


FIG. 6B. Courier.

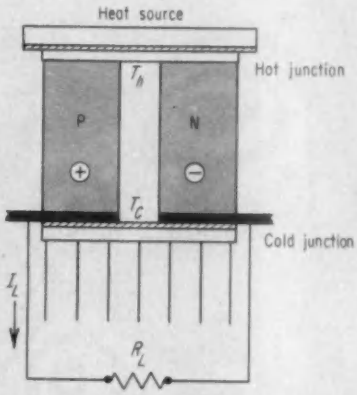


FIG. 7. Basic thermocouple power generator.

shift from sea level to outer space, cell efficiency, power and voltage loss due to high cell temperature, loss of transmission through matted glass cell cover, number of cells in series to yield battery charging voltage, projected cell area, angle of incidence, and number of parallel series strings to furnish required power. Blocking diodes must be included in each parallel cell group to prevent the battery from discharging into the "dark" resistance of non-illuminated groups. A shadowed cell in a series string can seriously reduce string output.

Cells are selected and matched for current at optimum load for use in a series string, and for voltage of the series string at optimum load to meet the required bus voltage. The system must have sufficient capacity so that the operating point on the cell current-voltage curve never falls below the optimum load point. Coatings to raise cell surface emissivity and filters capable of rejecting ineffective photons will lower cell temperature.

Using a zener diode in parallel with the solar power supply and storage battery provides a means for limiting the maximum voltage of the power supply. Diode threshold voltage should be slightly above the charging voltage, and the diode should be rated to dissipate maximum excess power the cell array can supply. This way, regulation is within plus or minus 10 percent.

Watts per pound for a solar cell power supply varies depending on the way the cells are mounted and the protection they require. A 1 by 2 cm cell weighs about 0.25 grams. If 600 of these cells could supply a 10 watt system then the rating is 30 watts/lb. This is high since it does not include mounting and accessories. By another yardstick, present cells can supply 12 watts/sq ft of projected area.

Solar power supplies have been used in a number of space vehicles, including Vanguard I, Explorer VII, Sunray (Grebe), Lofti, Transit, Tiros, and Courier, Figure 6. The approach outlined here applies as well to ground installations, except that power supply capacity must be larger for similar loads because of the intermittent availability of solar energy.

Individual solar cells, cell modules, and tailor-made complete power supplies are available from a number of suppliers, including Hoffman Electronics Corp., International Rectifier Corp., Texas Instrument Co., and Electro-Optical Systems, Inc.

What's coming next

NP cells now under investigation have a better spectral response in 0.4 to 0.5 micron region than the PN type, and have also been found to be more resistant to radiation damage. Both characteristics are important in space applications. Increasing unit cell output is being attempted by concentrating solar energy. Another approach being studied for feasibility is the preparation of large area multicrystal cells by vapor deposition of a thin film. Cells of this type may be less efficient, but cost per unit power should be reduced. Developments such as these may bring the cost breakthrough that will permit wide scale use of solar cells in industrial power supplies.

THERMOELECTRIC POWER GENERATORS

The thermocouple system of Figure 7 converts heat into direct current power by the Seebeck effect. When a temperature differential is established between the hot junction T_h and the cold junction T_c of N-type and P-type elements, a voltage develops. The open circuit sum of the voltages across the two elements is known as the Seebeck voltage or coefficient in microvolts per deg C. In contrast to temperature sensing thermocouples, power thermocouples are low voltage, high current devices. Connecting a load across the cold junction terminals causes current flow. Maximum power output is achieved when load impedance matches internal thermocouple im-

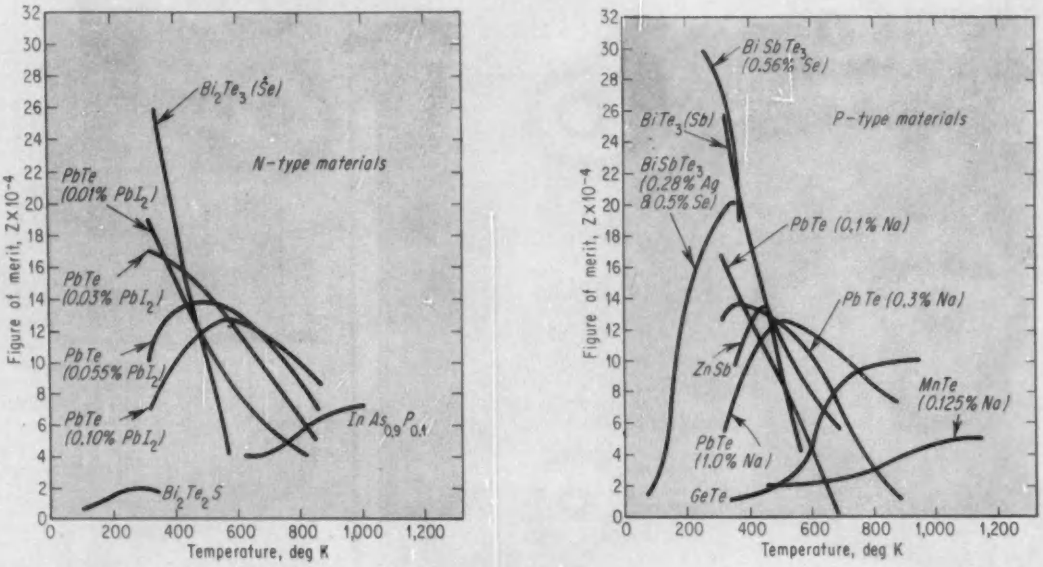


FIG. 8. Figure of merit vs temperature for various P and N-type materials.

pedance. Load voltage is about one-half open-circuit voltage under this matched condition.

Thermocouple performance

The thermoelectric generator is a heat engine with a maximum theoretical efficiency of

$$\eta = (T_h - T_c)/T_h$$

the well-known Carnot efficiency. Actually, I^2R, lateral heat, and heat conduction losses occur as well, and a more practical efficiency includes a function of a figure of merit Z. This figure depends on the measured thermoelectric properties of the materials over a given operating temperature range:

$$Z = \frac{(S_P - S_N)^2}{(\sqrt{K_P e_P} + \sqrt{K_N e_N})^2}$$

where S is the Seebeck coefficient, e resistivity in ohm-cm, and K thermal conductivity in watts/cm deg C, and P and N refer to the two thermocouple elements. These parameters are temperature dependent, and average values over a given operating temperature range are used. Then maximum thermocouple efficiency is

$$\eta = \frac{T_h - T_c}{T_h} \frac{\sqrt{1 + \overline{ZT}} - 1}{\sqrt{1 + \overline{ZT}} + T_c/T_h}$$

where $\overline{ZT}$ is average Z for temperature range T_c to T_h. Figure 8 gives figures of merit vs temperature for a number of N and P-type materials currently being studied.

The open circuit voltage of a complete generator depends on the number of thermocouples in series N, the Seebeck coefficients of the materials, and the temperature differential between the hot and cold junctions, ΔT,

$$E_{oc} = N\Delta T\,(S_P + S_N) \times 10^{-6} \text{ volts}$$

For maximum efficiency, electrical and thermal losses in each leg are balanced by adjusting cross-sectional areas. Equal length legs and constant area sections are used for simplicity. Mechanical as well as thermoelectric properties must be considered when establishing dimension ratios, plus the amount of heat flux to be absorbed at the hot junction.

Power system considerations

Since maximum hot junction temperature is established by the thermoelectric materials, heat transfer and rejection by the cold sink or radiator is a key factor in achieving high Carnot efficiencies. Convection, forced air, liquid, and evaporative cooling systems have been used. While large radiator areas are desirable, usually a compromise is reached based on required radiator to ambient temperature differential and permissible volume and weight.

Many types of heat sources have been tried, Figure 9. Nuclear sources of the radioactive isotope and reactor types are being studied for space, undersea, and remote area applications. Most existing generators use propane, butane, or natural gases, or gasoline, kerosene, or diesel oil.

Most heat sinks are cylindrical to provide adequate surface area for the hot junctions and compact thermocouple arrangement. The source temperature must be high enough to deliver the total required thermal watts, including the heat absorbed at the hot junctions and losses through insulation, supporting structure, radiation, and inefficient heat transfer. Burner efficiencies of 60 percent can be obtained in regenerative systems where the incoming air is preheated by the cold sink radiator before entering the combustion chamber. Allowance must be made in the mounting for thermocouple expansion and contraction, and the thermoelectric materials should be packaged in a hermetic container or encapsulated to prevent sublimation and oxidation.

Generator voltage regulation is poor and output voltage will vary inversely with load. Many generators work in conjunction with storage batteries in the same way as solar cell power supplies, and again, zener diodes can be employed for voltage limiting. A thermal feedback system for source

THERMOELECTRIC GENERATORS IN USE

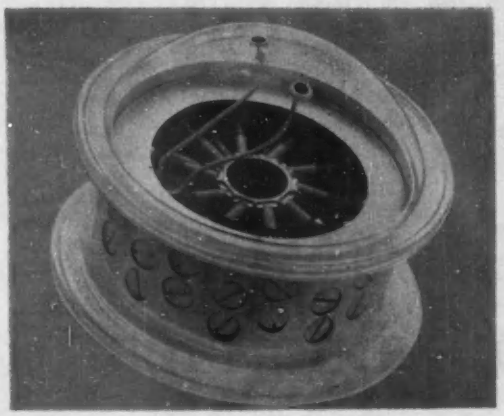


FIG. 9A. SNAP III by Minnesota Mining and Manufacturing powers generator by atomic reaction heat. It is intended to supply power to communication equipment in satellites and space vehicles.

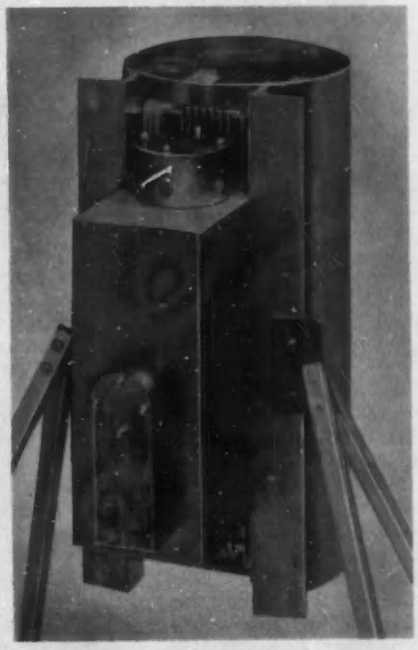


Fig. 9B. Propane-fueled 5-watt generator by General Instrument drives remote aids to navigation for U.S. Coast Guard. System includes nickel cadmium storage battery.

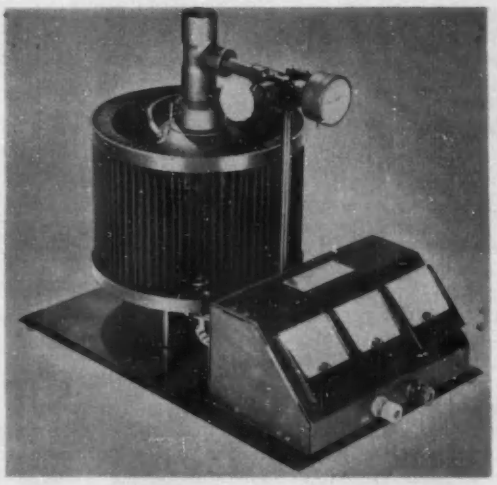


FIG. 9C. Another unit by 3M supplies remote cathodic protection for gas distribution line. Gas-fired generator delivers 10 watts.

temperature control is not adequate to regulate against load changes because of thermal inertia introduced by the mass of the generator. But such a system is useful in limiting maximum hot junction temperature to a safe value.

Thermoelectric generators are quiet, lightweight, compact sources of power requiring minimum maintenance. Units with capacities from 5 to 500 watts are being developed for the military. Power to weight ratios for complete generators of 5 to 10 watts per pound are feasible, and this figure should be bettered in the near future.

Some of the companies active in the field are Minnesota Mining and Manufacturing, General Instrument, General Dynamics, Texas Instruments, and Transitron Electronic. Figure 9 shows typical generators developed by 3M and General Instrument. The General Atomic Div. of General Dynamics is currently working on lightweight solar-thermoelectric panels for space applications with an estimated rating of 20 lb per kw when near Venus.

Thus, industry seems to have sufficient experience now for economic use of thermoelectric generators as control system power supplies.

REFERENCES

1. *MEAN PERCENTAGE OF POSSIBLE SUNSHINE, MONTHLY AND ANNUAL EDITION OF* 1960, a map for sale by Sup't of Documents, U. S. Government Printing Office, Washington, D. C., price 10¢.
2. WEATHER AND SOLAR VARIATION, C. G. Abbot, "The Journal of Solar Energy Science and Engineering", January 1957, p. 3.
3. *SOLAR RADIATION AVAILABILITY ON SURFACES IN THE UNITED STATES AS AFFECTED BY SEASON, ORIENTATION, LATITUDE, ALTITUDE, AND CLOUDINESS*, C. F. Becker and J. S. Boyd, "The Journal of Solar Energy Science and Engineering", January 1957, p. 13.

THE GIST: Thermoelectric device development has reached the point where specific engineering applications of Peltier heating and cooling are practical. Typical are the spot cooling of critical electronic components and the air conditioning of special enclosures. Beyond these, general purpose commercial and consumer applications will be feasible in the mid 1960's. The following examines characteristic current units of use to control engineers, samples commercial equipment, and gages the potential of thermoelectrics.

Temperature Control With Thermoelectrics

WILLIAM R. STUBSTAD
Collins Radio Co.

The successful application of thermoelectric devices has been primarily in areas that are of interest to control engineers; installations where their specific characteristics have suited them for spot cooling duty and for the control of critical temperatures. A few commercial developments have been made available to the public, but thermoelectric cooling and heating devices generally are not competitive with conventional techniques.

The major penalties of Peltier cooling are a poor coefficient of performance, high initial cost, and unusual power supply requirements, whereas the advantages are low weight, low volume, and high reliability. The coefficient of performance is defined as the heat output over the energy input, and can be greater than unity since it is not an efficiency rating but rather is a function of the energy required to transport the heat. In the shelter air conditioning application discussed later the coefficient of performance for the conventional vapor-cycle system is 1.2, while 0.8 is the value for the thermoelectric. Also, thermoelectric devices generally require high-current/low-voltage power supplies, a condition that leads to inefficient power units.

In the spot cooling, crystal oven, and air conditioning applications discussed below the advantages of the thermoelectric approach outweighed the liabilities.

Spot cooling and heating

Often the temperature sensitivity of a few components limits the maximum environmental temperature tolerance of a total electronic system. By thermally isolating these components and providing for cooling them, the over-all thermal performance of the equipment can be improved. Here thermoelectric spot cooling is more practical than conventional refrigerating techniques since heat dissipation requirements are small.

Figure 1A shows a simple spot cooler in which the heat dissipated by the component being cooled is pumped to a higher temperature heat sink by direct current flowing through the thermoelectric material. This basic approach is used in the germanium transistor cooler of Figure 1B. The transistor has a temperature limit of 100 deg C, whereas the other circuit elements can operate at 150 deg C. To raise the over-all equipment temperature tolerance to 150 deg C the transistor is mounted on a thermoelectric spot cooler and thermally insulated from the environment. The hot side of the cooler is attached to the chassis to provide a sink for transistor and spot cooler heat dissipation. This unit can pump 17 Btu per hr over a 50 deg C temperature difference to a chassis maintained at 150 deg C. Weight is slightly over 2 oz and volume including mounting plates is 1.2 cu in.

If temperature control is important the input power to the thermoelectric device can be provided by a control circuit consisting of a dc power supply, temperature sensor, and signal amplifier. This approach can be made double-ended, reversing the current flow through the thermoelectric material and causing heating or cooling

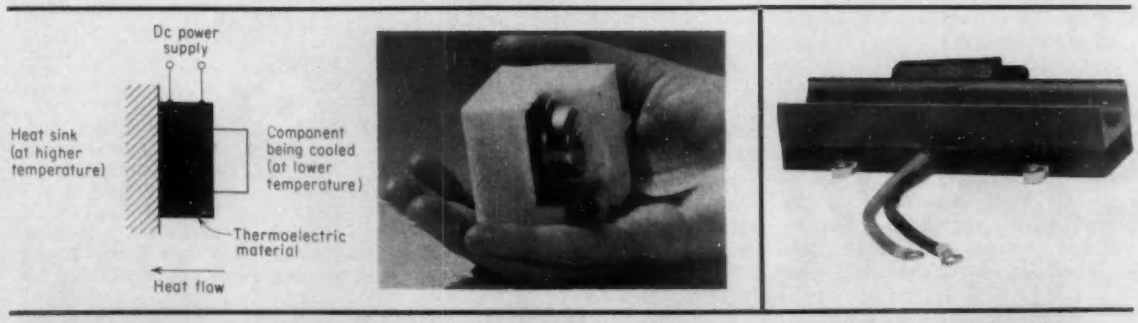


FIG. 1. The simple spot cooler of A is applied in the germanium transistor cooler of B. Note that the insulation has been partially removed for illustrative purposes.

FIG. 2. Crystal oven cooler combines with two-stage resistance heater.

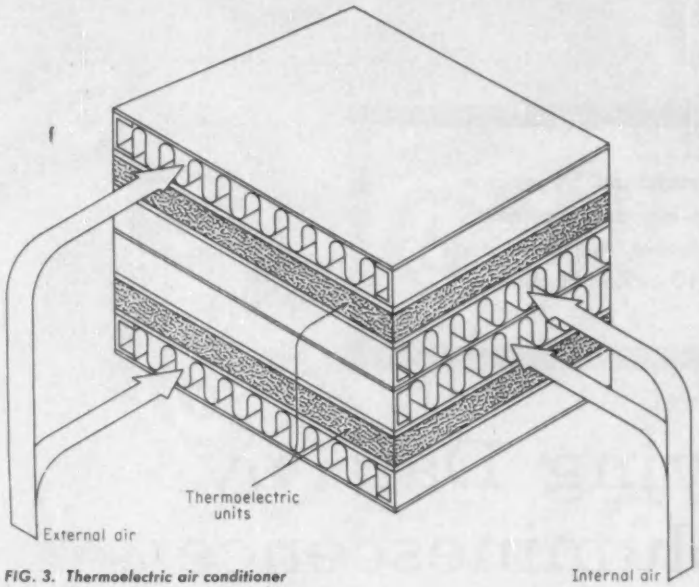


FIG. 3. Thermoelectric air conditioner for portable electronic equipment shelter.

depending on the environmental temperature.

The special high-accuracy temperature control system of Figure 2 maintains a temperature-sensitive component at a set temperature near 30 deg C within plus or minus 0.05 deg C over an environmental temperature fluctuation of from minus 55 deg C to plus 55 deg C. The thermoelectric unit operates continuously as a cooler, while a two-stage resistance heater oven attached to the cooler provides sensitive control. The heater wires are also the temperature sensors which, when incorporated in a bridge circuit, permit precise temperature control. The thermoelectric unit acts as a thermal bias, providing the system with the capability of below environment temperature stability.

Spot cooling and heating do not require a high coefficient of performance in the devices because power requirements are small, but the required current and voltage combinations may be difficult to achieve in some applications. For example, the cost of a thermoelectric unit would increase by a factor of three if the input current were reduced from 12 amp at 0.5 volts to 3 amp at 2.5 volts. It is doubtful whether a practical device could now operate at much less than 3 amp.

Enclosure air conditioning

Thermoelectric air conditioning systems differ from spot coolers and heaters. Normally, air conditioning involves sizable cooling loads, so the coefficient of performance becomes important. But at the same time the high power requirements permit the use of efficient power supplies in the range of 12 to 30 amp.

The thermoelectric system shown in Figure 3 is for a shelter with a 12,000 Btu per hr cooling load that must be transportable by helicopter. The solid state air conditioner replaces a conventional vapor-cycle system. Alternate layers of external air passages, thermoelectric units, and internal air passages are secured together to form a compact heat transfer unit. Blowers force environmental air through the external passages and shelter air through the internal passages, thereby transferring heat from the equipment and personnel to the environment with minimum heat transfer volume. Polarity control of dc power causes the air conditioner to change from a refrigerator to a heater for temperature control.

The thermoelectric air conditioner has a coefficient of performance equal to two-thirds of a conventional unit, but the thermoelectric unit including blower occupies only one-third the volume of the vapor-cycle unit. Costs for production quantities (200 units) are equivalent; however, the thermoelectric system weighs less than the vapor-cycle one. Up to this point neither unit appears to have the edge in performance, although the thermoelectric unit has an indirect advantage in design flexibility. It can be packaged in small volumes and placed within otherwise unusable areas in the shelter. It is apparent that, when all design parameters are considered, thermoelectric air conditioners can compete favorably with conventional units in specialized applications.

The status of thermoelectrics

- Recently released Russian information indicates their emphasis on various fields of endeavor. Thermoelectric device development and research was rated third, ahead of space exploration.
- Hughes Aircraft Co. has a three-stage thermoelectric cooler of commercial bismuth telluride which operates at 2 amp and 2 volts to produce a temperature drop from 25 deg C to minus 77 deg C.
- Minnesota Mining and Manufacturing Co. has developed a spot cooler for improving the performance of outdoor fluorescent lights.
- Westinghouse has initiated production of a thermoelectric bottled water cooler, and in addition can now provide spot coolers for operation up to 250 deg C. Previous applications include coolers for photomultiplier tubes, memory core circuits, crystals, and parametric amplifiers. A typical unit for housing a parametric amplifier has an internal cold chamber 8 by 12 by 6 in. and an internal cooling load of 120 Btu per hr.
- Collins Radio previously worked on the development of spot coolers in conjunction with Westinghouse. Collins' work is now being carried on with Ohio Semiconductors, Inc. on the applications discussed below.
- Ohio Semiconductors, Inc. is developing executive desk top water coolers, larger conventional water coolers, and portable freezer chests. They are also studying the application of spot cooling to vidicon or image orthicon tube faces, plus applications in the medical instrument field. Their estimate of the cost of cooling with standard thermoelectric materials is $1.80 per Btu per hr in small quantities and $0.20 per Btu per hr in quantity production.

While newer and more efficient thermoelectric materials will become available, present materials have sufficient performance potential to permit the development of practical devices. Commercial and consumer applications will come into common use, especially with the advent of efficient mass production techniques. The simple temperature control of sensitive parts will simplify the problems of control engineers, with satellite and space applications providing the first practical experience. Low maintenance and high reliability are desirable characteristics for remote applications in unmanned stations such as those used in the petroleum industry.

Electroluminescence—nonthermal radiation by electric excitation—has only recently been introduced commercially as a display technique. However, one manufacturer has already produced over 10 million EL devices.

Displaying Data by Electroluminescence

M. KRAWITZ and E. O. STONE
Sylvania Electric Products, Inc.

The elements of a simple electroluminescent lamp are a base or substrate on which the lamp is constructed, two electrodes (either or both of which may be transparent to allow viewing), and a phosphor-dielectric. The base is generally made of soft glass. Plastic and metal bases have also been used in some applications, particularly where a flexible lamp is desired. On this base a thin layer—less than a mil—of transparent conductive material like tin oxide is evaporated to form one electrode. A dielectric containing an electroluminescent phosphor forms the next layer, about 4 mils thick. Zinc sulphides have been shown to be the most suitable phosphors for EL lamps. A second electrode—either transparent or opaque, from a fraction to a few mils thick completes the assembly. When an ac potential is applied to the two electrodes, the phosphor embedded in the dielectric luminesces. There are almost no restrictions on size, shape, or contour.

Digital displays

A modification of the construction given above results in a numeric readout, Figure 1. Here an electrode on one side of the phosphor-dielectric has been broken up into nine segments. An ac potential applied between the proper EL segments and the common electrode displays the digits 0 through 9. A more complex arrangement of 14 segments can display all 10 digits and 26 letters. A variety of these numeric and alphanumeric display units are commercially available in sizes from 1 to 12 in. high. Pigtail leads, printed circuit board connectors, or direct solder pins are supplied. These EL readout devices are attractive for space saving, since their size can be virtually the dimensions of the substrate. On the other hand, extremely large character displays can be made. The units are flat and have little depth, so they can be read over a wide viewing angle. Light contrast with ambient can be improved by applying a thin lacquer containing a dye on the viewing surface.

The brightness characteristics of EL lamps are a function of both voltage and frequency, Figure 2. Note also that brightness falls off fairly rapidly from turnon until it reaches about 50 percent of initial brightness after about 2,000 hours of operation. It continues to grow dim, but at a much slower rate from this level. The current and power consumed by an EL lamp, Figure 3, shows that these devices have essentially the characteristics of a lossy capacitor. The low power consumption of EL lamps is one of their main advantages.



FIG. 1. A commercially available nine-segment numeric display module.

Switching techniques

The switching of numeric or alphanumeric EL displays may be accomplished by mechanical, electromechanical, electronic, or electro-optical means. Some type of matrix is required. If, for example, decimal information is supplied, the matrix must provide the proper outputs to light the required segments for the display of a particular character.

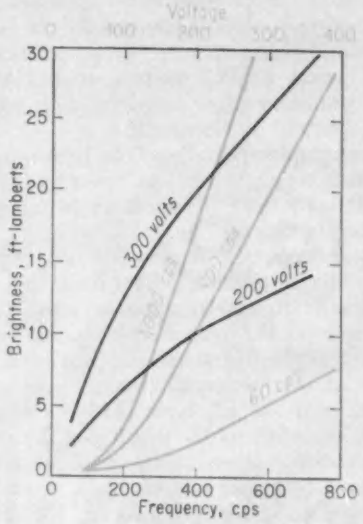


FIG. 2. Light output of EL lamps varies with voltage and frequency.

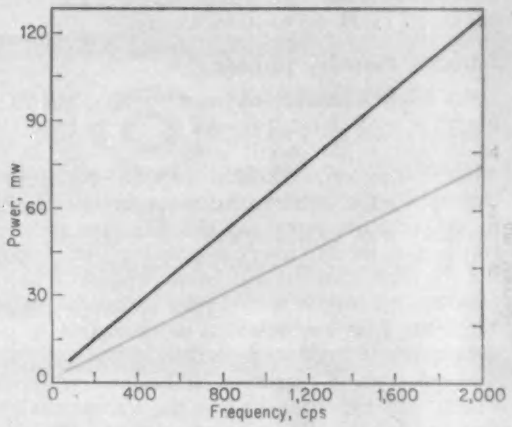


FIG. 3. EL units have current and power characteristics of a lossy capacitor. Note that the values indicated are for 1 sq in. of illuminated area.

A simpler approach than rotary switches, relays, or diode matrices is to use either an electroluminescent-photoconductive (EL-PC) or neon-photoconductive (NE-PC) switching matrix. Figure 4 shows an EL-PC decimal-to-numeric translator. Here 10 electroluminescent bar lamps, a properly coded mask, and an array of photoconductive gap cells provide a matrix for switching a seven-segment numeric. For example, when the voltage is applied to bar lamp 7, light will pass through the holes in the mask directly in front. The proper PC gap cells are exposed, and current will flow only to the segments required to display the digit 7. Where it is more convenient to drive the translator from dc voltages, the bar lamps may be replaced with neon glow lamps. Matrices of this type are available for decimal to numeric, binary to decimal, and binary to numeric conversion. The principle can be applied other functions, such as AND and OR logic.

Cross grid displays

Since most EL displays are made by graphic arts techniques, the electrodes may be made in any configuration. Sets of electrodes consisting of long narrow conductors at right angles to each other may be produced. A phosphor-dielectric is sandwiched between the two electrode sets; one set must be transparent. The intersection of a pair of electrodes (one on each side of the EL material) forms an electroluminescent cell. It is possible, therefore, to excite any cell in the matrix by addressing the proper coordinate conductors. Some light is also emitted along the entire length of the two energized conductors. The contrast ratio between the intersection and the line is generally from four to 16, depending on the type of EL phosphor used. This ratio may be increased by using the proper voltage at the various electrodes. These matrices are com-

FIG. 4. An EL-PC switching matrix for a seven-segment numeric shows how the digit 7 is displayed.

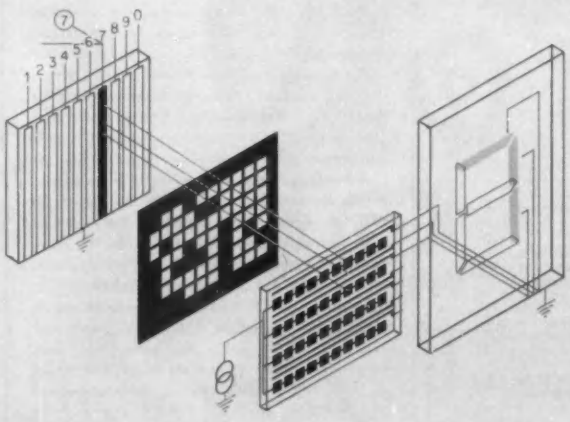
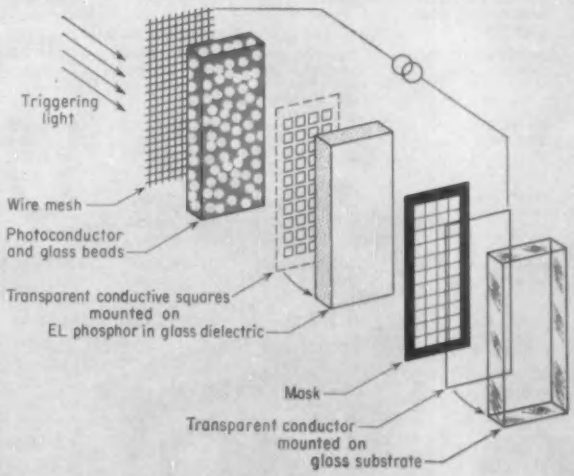


FIG. 5. Method of producing a memory element with EL and PC cells.



mercially available with resolutions from 4 to 50 lines per in., in panels up to 10 in. square.

Bistable memory panels

An EL-PC bistable memory panel is shown in Figure 5. A fine mesh is used as one outside electrode and a transparent conductive layer as the other. When an ac potential is applied between the electrodes, the total voltage appears across the photoconductive layer and the EL layer in series. In the dark the PC layer's impedance is many times the impedance of the EL lamp. Therefore only a small fraction of the total voltage appears across the EL layer. This low potential is insufficient to produce appreciable illumination.

If, however, a triggering light source is applied either from the mesh side or the transparent conductive layer side (the viewing side), the PC layer's impedance will be reduced to a fraction of the EL layer's. As a result, most of the applied potential will appear across the lamp. Once triggered, light feedback from the EL layer illuminates the photoconductive layer and keeps it at a low impedance. Individual cells may be triggered by practically any light source. When sandwiched behind the bistable panel, an EL cross grid may be used as the trigger source. Or a projected light may be used to trigger the memory panel from either side.

Applications

The three types of EL display devices detailed above—digital displays, cross grid panels, and bistable memory displays—are suitable for a host of military, industrial, and commercial applications.

• **Alphanumeric readout**—Scoring boards; stock quotation boards; and plane, train, and bus traffic control boards can use alphanumeric EL devices. They can also be used in paging systems and for readouts in digital measuring instruments.

• **Tracking displays**—Lines and dots to indicate the position of ships, missiles, or planes may be displayed using EL-PC tracking units. A memory panel containing many individual cells may be triggered optically or electrically.

• **Photographic recording**—The light output of EL displays is highly actinic, so contact prints may be made directly from the small lamps for permanent recording of data on film.

• **Oscilloscope-type figures**—Lissajous figures have been portrayed on an EL layer built on a piezoelectric ceramic panel. By applying pulse voltages to the edges of the piezoelectric panel, mechanical energy is propagated across the panel and the intersection of the mechanical waves causes an electric field to light the EL layer. This technique could well be extended to TV picture display.

In these and other possible applications, EL displays have a number of advantages, as well as a few important drawbacks. In general, EL displays are fairly low in cost and have very low power consumption, a wide viewing angle, a great variety of sizes, sufficient speed (millisecond range), and little likelihood of catastrophic failure. On the other hand, while EL panels will give appreciable light almost indefinitely, in applications requiring considerable brightness, the half-brightness lifetime of several thousand hours may be a limitation. Brightness change during life is substantially reduced by operation of the EL device through a series resistor. Even after thousands of hours of operation, brightness variations between units are almost unnoticeable. Though power required is low, the voltage and frequency to obtain suitable brightness may not be readily available. Display panel cost itself is low, but as with similar devices, an encoder is required for numeric and alphanumeric operation.

WHAT'S AVAILABLE IN EL DISPLAYS

	Simple panels	Alphanumerics	Cross grids	Other
Controls Co. of America El Segundo, Calif.	Plastic-based, up to 144 sq in., in four colors			Custom panels, dial faces*
Ericsson Telephones Ltd. Beeston, Nottingham, England	Up to 77 sq in.	Up to 8 in.	20 x 20 line array	Block indicators, power supplies, translators
General Electric Co. Cleveland, Ohio	Flexible plastic-based up to 164 sq in. High 60-cps brightness			
Kearfott Div., GPI Little Falls, N.J.		EL panels driving miniature fiber optic readouts*	High resolution (300 ll/in.) up to 5 x 5 in.*	
Melpar, Inc. Falls Church, Va.		2-in., 14-segment. One model for multiple packing	•	•
Radio Corp. of America Harrison, N. J.	Glass-metal laminates up to 256 sq in.	Up to 12 in.	Up to 10 x 10 in.	Dial faces, illuminated components*
Sylvania Electric Products, Inc. New York, N.Y.	Up to 1,152 sq in.	Up to 12 in.	Resolution up to 50 ll/in., sizes up to 10 x 10 in.	Translators, encoders, memory panels, image converters
Westinghouse Electric Corp. Bloomfield, N.J.	Glass, metal, plastic-based up to 144 sq in.	Glass-based up to 4 in.		Dial faces, plotting boards*

*Available on special order

SOMETHING NEW

Recent studies at Philco Corp.'s Research Center into electrical and optical properties of cadmium sulfide have shown that its fluorescence can be quenched by the application of small dc voltages across the phosphor. This experimental work could lead to electro-quenchable phosphor display elements with vast potentialities. Combined with photosensitive elements, these EQ sources could be made into electro-optical devices for data processing circuitry where input and output are optical and the coupling path is electrical.

Advantages foreseen in the EQ phosphors should be obtained mostly from the use of the small dc signal rather than the high voltage, high frequency potential needed for EL units. The small voltages (about 10 vdc) are desirable because they can be conveniently handled by transistors and PNPN switches, and techniques of handling dc pulses are highly developed. Also, an EQ-PC device has a dc input and output, compared to the ac input and ouput of EL-PC units, which require modulation and demodulation. Ed.

Molecular electronics, the last word in solid state, does away with components and wiring as we know them. Instead, single blocks of material perform complicated circuit functions. Some of these blocks are ready for production now. Here's how they're designed and made, and what ME will mean for the control engineer.

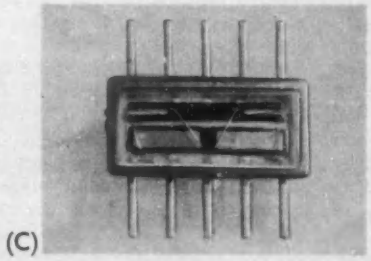
Molecular Electronics–
New concept for control

H. V. NOBLE, Electronic Technology Laboratory
Wright-Patterson Air Force Base

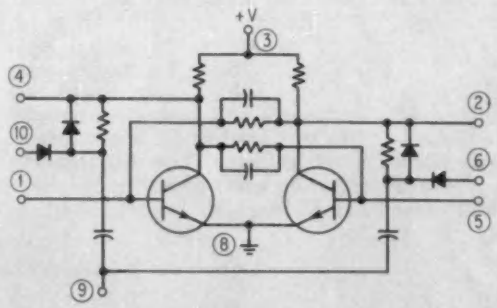
Molecular electronics is the tailoring of materials–primarily silicon at present–to perform electronic functions such as oscillation and amplification. Individual components–tubes or transistors, resistors, capacitors, inductors –are forgotten. Instead, all the know-how of semiconductor technology is focused on turning a single block of material into an oscillator, an amplifier, an adder, a gate, etc. These single bits of material are called "functional electronic blocks" or "FEBs" (pronounced feebs). They offer extreme size reduction, extreme reliability.

Many effects combined

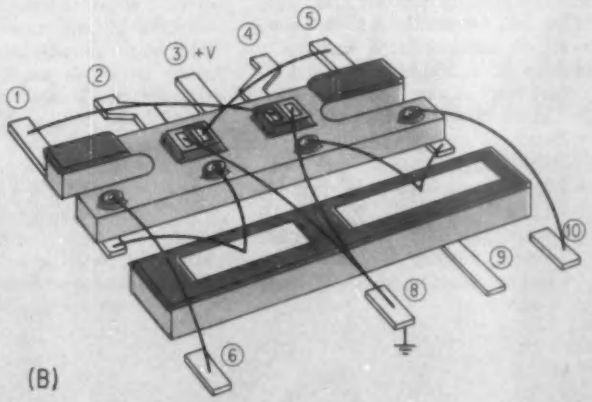
Transistors and diodes are familiar semiconductor devices. Varactor diodes, whose capacitance is a function of the reverse bias applied to a semiconductor junction, are also well known. Single crystal semiconductors have resistance that is a function of their size and shape and can be modified by alloying or diffusing other materials into the crystal structure. Proper combinations of resistance and capacitance lead to phase shift effects equivalent to inductance. These and



(C)



(A)



(B)

FIG. 1. Texas Instruments Type 502 bistable multivibrator illustrates TI's approach to molecular electronics. Circuit, A, is transformed into FEB, B and C, by diffusing P-type silicon through oxide coating on N-type silicon wafer, selectively removing the oxide, diffusing N-type material for emitters, applying metal contacts, removing unwanted P-type material by selective mesa etch, and separating the upper and lower parts of the block.

TWO FUNCTIONAL ELECTRONIC BLOCKS

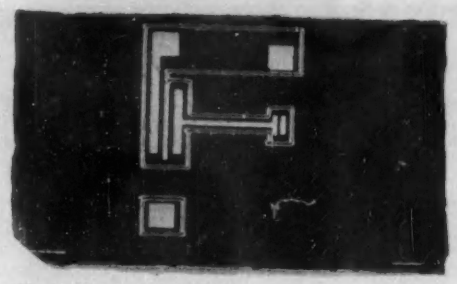


FIG. 2. Westinghouse UNIBI is one of a set of low power (50-milliwatt) amplifiers.

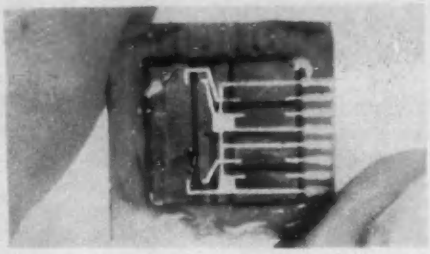


FIG. 3. Solid silicon flip-flop by Philco.

HIGH LEVEL FEB AMPLIFIERS

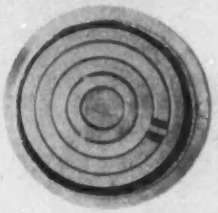


FIG. 4 Internal view of two-stage Westinghouse amplifier with 5-amp output, current gain of 1,000.



FIG. 5. Water-cooled amplifier by Pacific Semiconductors delivers 2,000 watts.

other solid state properties (Georgia Institute of Technology, under an Air Force Contract, has turned up some 150) are exploited in FEBs.

Right now, most of the effort in the field is being expended in developing like functions, i.e., FEBs which duplicate devices that could be made with ordinary components. Often, the FEB has areas serving as resistors, capacitors, transistors, and diodes, even as the circuit it duplicates, Figure 1.

As time goes on, more sophisticated FEBs that can have no conventional circuit equivalent will be developed. For example, a pressure sensor might be an amplifier whose gain is a function of pressure. Or it might generate a range of frequencies—audio for wire transmission, or rf for remote transmission via an antenna—proportional to pressure. If the distance were not too great, a piezoelectric sensor might supply its own transmitting power. No manner of loading on the receiver will affect the sensor's performance.

The list of molecular electronic devices already produced includes:

- Low level amplifiers—various input impedances, Figure 2
- Tuned amplifiers—bc band
- Bandpass amplifiers—from 250 to 1,500 kc
- Multivibrators—bistable, astable, Figure 3
- Multistage high level amplifiers—power outputs to 2,000 watts, current gains to 10,000, Figures 4 and 5
- Switches—several types, up to 10 positions
- Pulse generators—with 100-kc frequency range and pulse width under 1 microsec
- Ring counters—four-stage, field effect
- Oscillators—fixed, 100-2,000 kc; variable, 500-2,000 kc
- Variable pulse generators—voltage variable amplitude and repetition rate

Approach to design

In the design of a functional electronic block, the circuit function usually dictates the number of P and N layers, their thickness, doping level, and junction gradation. The most sophisticated part of the circuit usually requires the most layers. With the doping level somewhat fixed, the biasing, coupling, and compensation (especially thermal) needed to optimize the phenomena become geometric considerations, keeping in mind the techniques available (photoresist and etchants, masking for diffusion steps) to achieve the geometry. Internal connections, signal and power paths, location of contact areas, protection of exposed junctions—all have to be considered.

Because FEBs are a direct application of semiconductor techniques well known to that industry, advances such as epitaxial growth and planar construction are directly applicable to FEB fabrication. Once suitable controls are established, FEB rejects should run no higher than transistors do now. In a FEB, one is interested only in over-all performance, not whether each active or passive area be held to very close tolerances. Matching between active elements should be improved since they are made of as nearly equivalent material as it is possible to conceive.

The packing density of molecular electronics is almost beyond belief. An audio amplifier with a gain of 50 db can be produced in a FEB measuring $\frac{1}{8} \times \frac{1}{4} \times 2{,}100$ in.—1,600 of these per cu in, 230,000 per cu ft. Translating this into the number of transistors, capacitors, etc., that would make an equivalent circuit, these 230,000 FEBs represent over two million conventional parts.

Of course, this many FEBs couldn't be designed into such a small space. The interconnections between FEBs take up room, and some method of cooling is required even though the power dissipation is small. FEBs in their present form are hermetically sealed with the necessary terminations protruding from the package. The maximum packing density so far, with hermetic packages, has been achieved by Texas Instruments using resistance welded point-to-point connections of wire ribbon and terminal pins peripheral to the largest area of a single FEB. These terminal pins plug into a layered matrix, and 10 to 13 FEBs are stacked.

At the present time, Westinghouse and Texas Instruments are well in the lead in molecular electronic research and development—each having been given healthy support by the Air Force. However, most other semiconductor manufacturers have indicated strong interest, and some have made a few types of the devices. None of these devices are really in production, although some could be if encouraged by enough orders.

Phasing-in FEBs

One of the problems yet to be solved is whether to optimize FEBs for each specific system or to standardize on a series of FEBs that will have the most popular usage and then optimize a few "specials". It seems the trend will be toward standard items, but who will decide what the standards will be? Considering past experience, it is unlikely that the military will have the power. As more producers get into the act, each will try to get its share of the market by making its own standards—witness the number of transistors and diodes on the market today. Perhaps the high first cost to make each item will limit the number of entries into this new field.

Who will make molecular electronic items? The semiconductor manufacturers are in an excellent position to start. To avoid putting design engineers into the untenable position of being merely parts assemblers, many equipment manufacturers will be forced into making their own FEBs. As the need for resistors, capacitors, and other conventional parts declines, present parts manufacturers will have time to align themselves with molecular electronics. In the best position by far are concerns who make both electronic equipment and semiconductor components.

The first FEBs to be available in quantity will be those that go into computers. Digital data processing equipment is an ideal application for ME because these systems are based on a few circuit functions duplicated many times over with complex interconnections. As might be expected, stabilized linear devices are harder to design than pulse devices, but analog items and digital-to-analog converters will be available. Because of ME's potential reliability, system designs will be less inhibited by trade-offs and safety factors. Low power radio links will permit control on the move.

At molecular electronic's current rate of advancement, some ME systems can be designed and constructed within two years with items available from three or four companies. Within five years, most semiconductor manufacturers will be in the molecular electronics business, and reasonably sophisticated systems can be designed from available FEBs. In ten years, ME should be in about the same position as transistors are today.

Interestingly enough, there will be an urgent need for better process control in the manufacture of FEBs themselves. They require tighter control of chemical processes, positioning, and area size and shape than any components now in use. The control engineer will have a significant part in shaping the future of molecular electronics to meet his needs.

DESIGNING FUNCTIONAL ELECTRONIC BLOCKS

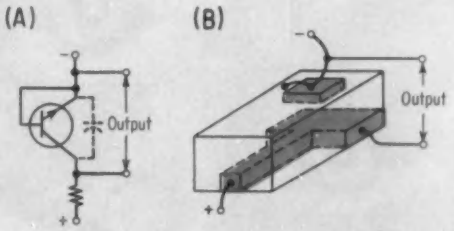
The Semiconductor Div. of General Instrument Corp. is currently executing orders for microelectronic logic circuits (packaged combinations of their standard microdiodes, microtransistors, microcapacitors, etc.) and is evaluating the promise of molecular electronics.

According to Alan Stanley, the Division's Asst. Director of R&D, design of a molecular electronic block, see figure, starts out with an ordinary semiconductor circuit that is breadboarded and tested with ordinary components. Next the designer must consider the solid state techniques needed to form the circuit elements, and combine them into a three dimensional topology that will perform the circuit function. He can include PN junctions for diodes and transistors, diffused semiconductor material of the proper dimensions for resistance, junctions or oxide layers separating two conducting layers for capacitance, and magnetic films of various shapes for inductance.

With experience, ME engineers will probably be able to design in terms of circuit rather than component function; this should simplify the procedure and lead to devices that can do things ordinary circuits cannot.

When a solution is found, the next step is to lay out photolithographic masks to be used in selectively diffusing the several layers of the first "state of the art" model. This ME block is subjected to complete measurements to see whether it conforms to design specifications. Assuming its performance is less than perfect, the designer tries to change manufacturing process variables to bring the device into line with the spec. Failing in this, he must change the design variables and make a new set of masks.

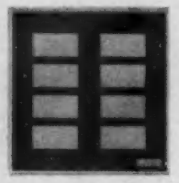
As soon as a state of the art model works as required, a pilot production line is set up to get data on reproducibility and yield. This is relatively easy because all the techniques are familiar from semiconductor component lines. At this point (indeed, if not before) a systems man is called in to tell the circuit and solid state engineers how the device is to be mounted and connected to other circuits. When these requirements are met, the ME block is ready for production.

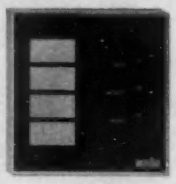


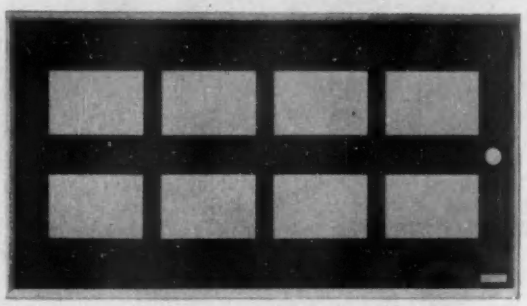
Simple sawtooth oscillator begins with conventional circuit, A, that is tested with standard components. Designer then seeks solid state topology, B, that will carry out component functions. Here areas of N-type silicon are diffused into upper and lower surfaces of P-type silicon block; section at right is equivalent to NPN transistor, strip at lower left to resistor. In practice this block (about 10 mils across) would probably be part of a larger block with a more complicated function.

NEW PRODUCTS

SOLID STATE CIRCUIT allows miniaturized annunciator panels.





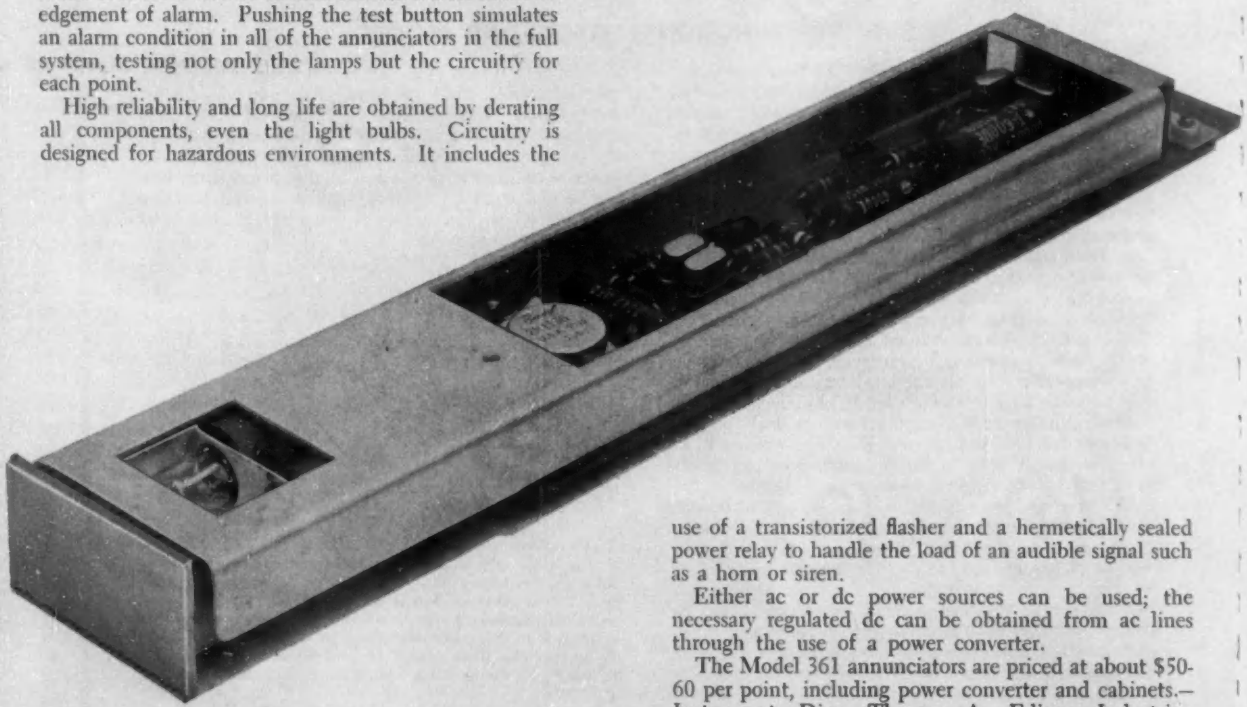


Miniature annunciator panels with as many as eight alarm plates in a 5 x 5 in. area are now available as the result of using redesigned, all solid state circuitry. The heart of the new annunciator system is a rugged, channel-mounted module only ¾ x 1½ by 10 in. (shown below) which is easily plugged into several standard cabinets. Either standard 2 x 3 in. nameplates or new miniature ¾ x 1½ in. plates may be had. All electronic components are mounted on an etched circuit board in the slide-in module.

Eight standard sized plates can be packaged as shown in the bottom photo at right. Up to 48 such units can be supplied in a single cabinet. Eight of the smaller alarm modules are available on the 5 x 5 in. panel, upper left. A number of these cabinets can be mounted in a group. Acknowledge, reset, and test pushbuttons can be supplied with four alarm circuits in the same size panel, as shown at upper right.

The annunciators may be operated by either NO or NC field contacts by simply varying external connections. Two operational sequences are available: automatic or manual reset to normal condition after acknowledgement of alarm. Pushing the test button simulates an alarm condition in all of the annunciators in the full system, testing not only the lamps but the circuitry for each point.

High reliability and long life are obtained by derating all components, even the light bulbs. Circuitry is designed for hazardous environments. It includes the use of a transistorized flasher and a hermetically sealed power relay to handle the load of an audible signal such as a horn or siren.



Either ac or dc power sources can be used; the necessary regulated dc can be obtained from ac lines through the use of a power converter.

The Model 361 annunciators are priced at about $50-60 per point, including power converter and cabinets.—Instrument Div., Thomas A. Edison Industries, McGraw-Edison Co., W. Orange, N. J.

Circle No. 309 on reply card.

MICRO SWITCH Precision Switches



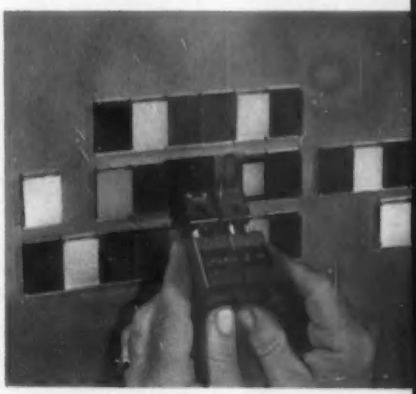


Save 50% on space. Indicator and switching unit are combined in one device to save panel space.

Start your panel design with the

Reliability, Styling and Flexibility of MICRO SWITCH lighted push-button switches

The flexibility of MICRO SWITCH "Series 2" lighted push-button switches enables you to precisely tailor your control panel to your requirements. Hundreds of switch and indicator combinations can be assembled by simply snapping together the correct modular parts. Their clean, modern styling complements your panel design without dominating it. Most important, any of the 18 switch units you select has MICRO SWITCH reliability. That's why these "Series 2" switches serve on some of the most crucially important control panels in the world. Write for the colorful Catalog 67, or see the Yellow Pages for the nearby MICRO SWITCH Branch Office.



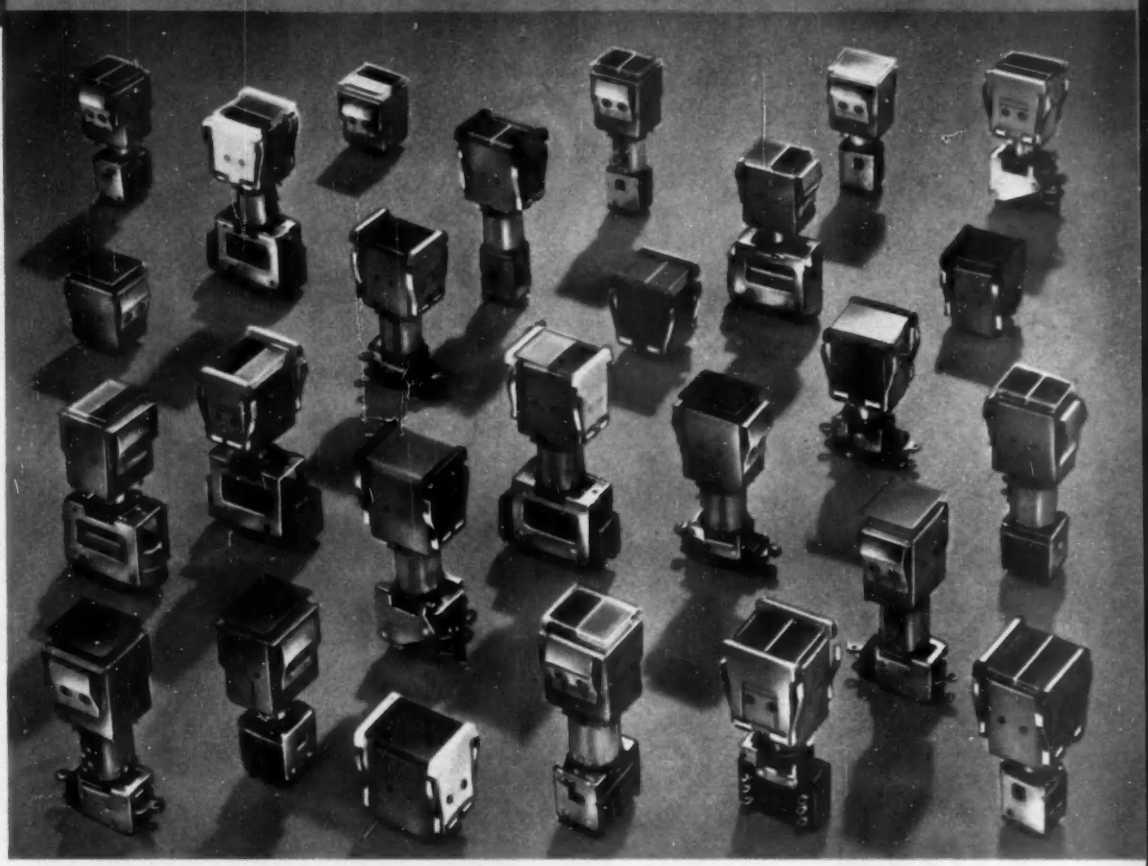
It's a snap! Modular parts snap together and then snap into panel slots without tools.

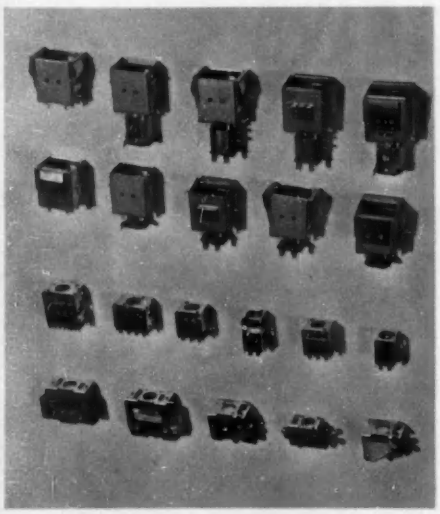
MICRO SWITCH . . . FREEPORT, ILLINOIS
A division of Honeywell
In Canada: Honeywell Controls, Limited, Toronto 17, Ontario

Honeywell
MICRO SWITCH Precision Switches

HONEYWELL INTERNATIONAL
Sales and service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

MICRO SWITCH Precision Switches





Eighteen different switching units are available to match virtually all circuitry requirements.

Hundreds of switch and indicator combinations ...with MICRO SWITCH reliability

The functional color combinations on "Series 2" switches can be split laterally or longitudinally. Up to four colors can be used behind each display screen. Projected color makes it possible for the display screen to change color to indicate a change in the circuit.

Available switching units include hermetically sealed units, small but rugged long-life types and space-saving subminiature assemblies. Momentary-contact or alternate-action units are available in a choice of circuitry to exactly match requirements. Insist on MICRO SWITCH reliability by specifying "Series 2" push-button switches for your panel. You may obtain prompt engineering help by simply checking the Yellow Pages for the MICRO SWITCH Branch Office. Send for Catalog 67.

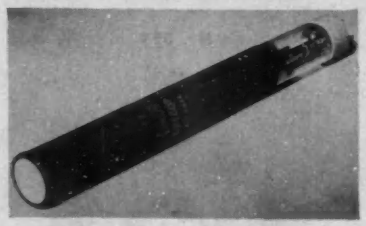
MICRO SWITCH . . . FREEPORT, ILLINOIS
A division of Honeywell
In Canada: Honeywell Controls, Limited, Toronto 17, Ontario

HONEYWELL INTERNATIONAL
Sales and service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

Honeywell
MICRO SWITCH Precision Switches

NEW PRODUCTS

DATA HANDLING & DISPLAY



FIBER OPTIC CRT

This 1⅞-in. cathode ray tube has a fiber optic face plate containing 6 million individual glass rods. This technique allows the trace to be brought to the face of the CRT without any parallax. The normal light transmission efficiency of a lens system of about 6.3 percent is increased to 85-90 percent. The new tube has an over-all length of 13½ in. with a useful screen diameter of 1.2 in. Heater supply of 6.3 volts at 600 ma, grid No. 1 voltage of −40 to −110 volts, grid No. 2 voltage of 1,000 volts, and accelerator voltage of 10,000 volts are required. Sample tubes are priced at about $900. Tubes in sizes up to 5 in. in diam can be made available.–Electronic Tube Div., Allen B. Du Mont Laboratories, Divs. of Fairchild Camera and Instrument Corp., Clifton, N. J.

Circle No. 310 on reply card



PRINTS TWO WAYS

Designed for use with the manufacturer's 1401 computer, this 1404 printer is said to be the first to combine printing of either individual cards or continuous paper forms as direct computer output. Changeover involves moving chain printing mechanism from one printing station to the other. Maximum card output is 800 per min depending upon number of lines printed, line spacing, and method of input. Paper forms can be printed at up to 600 lines per min. With first delivery scheduled within two years, the printer sells for $85,500 and rents for $1,550 per month. Adapters are also required to fit the unit to the 1401.–International Business Machines Corp., Data Processing Div., White Plains, N. Y.

Circle No. 311 on reply card

HIGH SPEED GENERATOR

Capability of displaying up to 100,000 characters per sec is the feature of the new TD-549 solid state character generator. Additional units can be operated in parallel to provide an unlimited number of characters and multilingual output with no speed reduction. Special symbols, sizes, and languages can be provided with simple plug-ins. The device accepts signals from computers, tape readers, and data links, and normally displays on a cathode ray tube. Price: $860.–Transdata, Inc., San Diego, Calif.

Circle No. 312 on reply card



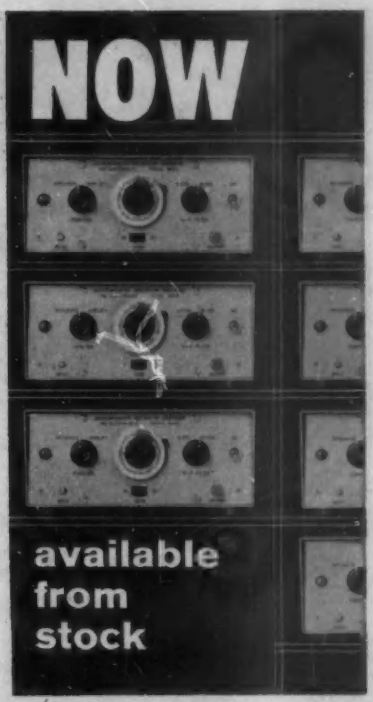
PULSE CODE TELEMETERY

By using a pulse code system, this high speed telemetering device for remote process conditions gathers and digitally displays data in just 3 sec. The illuminated in-line display includes both point and function identifications with digital data to six figures and liquid level to ⅛-in. increments. The single channel system is designed for readings of liquid level and temperature.–Dynel, Inc., Sub. of Varec, Inc., Los Angeles, Calif.

Circle No. 313 on reply card

MULTI CHANNEL DIGITIZER

The Model 1043 information logger samples a channel of analog information for 100 microsec, quantizes it, and assembles it in a series of digital words. Standard models provide sequential sampling for up to 30 channels. Over-all multiplexing and conversion accuracy is to within 0.1 percent based on 5-volt maximum



MB model N504 INTEGRATOR AMPLIFIER

- Measure acceleration, velocity, or displacement with conventional accelerometers and vibration meters.
- Measure acceleration or velocity from accelerometer input with standard voltmeters.
- Convert accelerometer signals to velocity for automatic control of vibration exciter displacement, velocity or acceleration.
- Eliminate need for cathode follower and power supply.

SPECIFICATIONS

Frequency Response:	Amplify Position (5 cps filter)
	10–10,000 cps ± 2%
	5–10,000 cps ±7%
	Integrate Position (–6 db/octave)
	10–2,000 cps ± 5%
	5–2,000 cps ±10%
Sensitivity:	Amplify Position Maximum gain = 100
	Integrate Position 1 mv(rms)/"g" peak converted to 96.3 mv (rms)/in./sec.(rms)
Input Impedance:	Greater than 200 megohms
Output Impedance:	Less than 600 ohms

Complete technical details in Bulletin 131. Write...

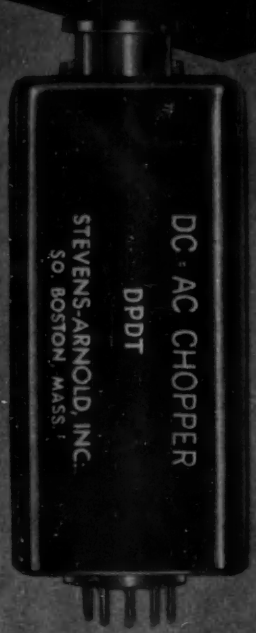
MB ELECTRONICS

A DIVISION OF TEXTRON ELECTRONICS, INC.
1101 State Street, New Haven 11, Conn.

CIRCLE 189 ON READER SERVICE CARD 189

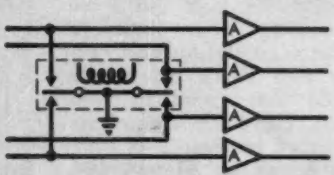
NEW

twin contact miniature DC-AC choppers



Eleven types, both single and double pole.
Long life.
Low noise level.
Extreme reliability.

DPDT
LOW COST
FULL ISOLATION



A



Write for Catalog 515-B

STEVENS INCORPORATED ARNOLD

QUALITY SINCE 1943

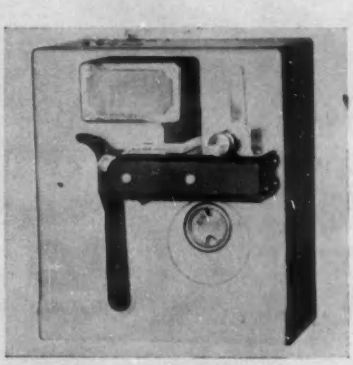
7 ELKINS ST., SOUTH BOSTON 27, MASS.

S/A 1436

NEW PRODUCTS

input. Data are available on a display board 10 at a time or, during low speed acquisition, at intervals of 1-60 sec.–Lockheed Electronics Co., Plainfield, N. J.

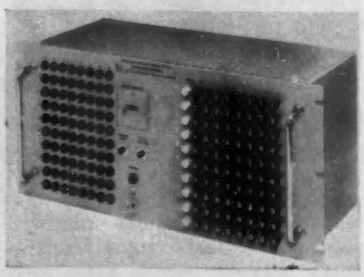
Circle No. 314 on reply card



ANEMOMETER READER

This high speed tape reader uses hot-wire anemometer sensing elements to offer top reliability at various speeds up to more than 500 in. per sec. In operation, air is sucked through a slit on one side of the tape. A series of apertures corresponding to the tape's hole pattern is opposite the slit on the other side of the tape. The tape holes port air from the apertures to the slit suction source. Presence of a hole permits air to flow through an aperture, which is bridged by a hot-wire element. Voltage changes are sensed through a bridge circuit to read the tape. A vacuum system cleans the reading station. The unit reads standard five, six, seven, or eight-hole tapes, transparent or opaque, paper or plastic. –Soroban Engineering, Inc., Melbourne, Fla.

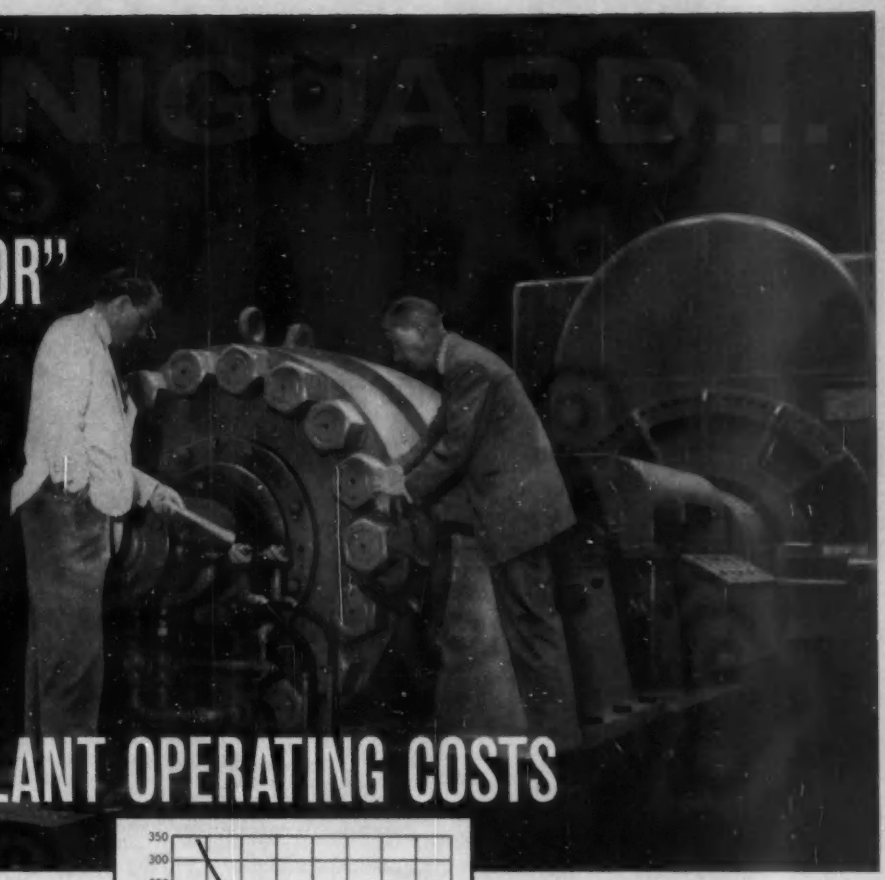
Circle No. 315 on reply card



PROGRAM TAPES

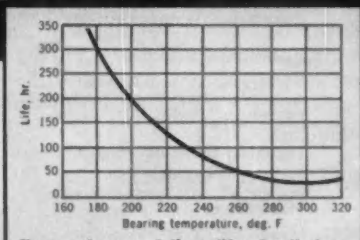
Programming and automatic punch control are combined in the PS-425 program simulator, which is designed

THE "SUPERVISOR" THAT SHOWS YOU EASY PLACES TO CUT PLANT OPERATING COSTS



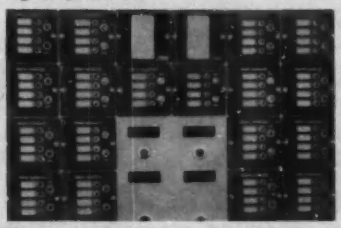
There are three basic ways to combat the steadily rising cost of plant operation. Two of them are hard ways: buying higher capacity initial equipment, or, trying to find more efficient equipment. So many advances have already been made in these directions that any overall economy you may gain in the future promises to be small.

But the third way to save—and this is the easy one—is to increase the *reliability* of your equipment, thereby lowering your maintenance expenses and perhaps even reducing the amount of standby equipment needed. *Omniguard* is a proven *supervisory system* that enables you to do just this. It continuously supervises bearing temperatures in your heavy rotating equipment, preventing bearing failures and *extending* bearing life, sometimes by years. Omniguard also monitors lube oil pressures, pump suction and discharge pressures, and other variables of a critical nature. Monitors and indicators installed at any convenient location away from the equipment, display the readings and provide warning signals and automatic shut-down of equipment if desired.



Temperature vs. fatigue life of a tin-base babbitt bearing at a unit load of 2000 psi.

Dozens of machines at as many different locations can be watched from a single panel for signs of excessive bearing operating temperatures.



Omniguard keeps constant watch on the important temperatures and pressures in your plant—makes it easy for you to avoid the expensive repair jobs and down time that would otherwise be part of your operating expense.

For complete information on the Edison Omniguard System, and the variations available for different kinds of machinery, write for Catalog 3036D.

Thomas A. Edison Industries
INSTRUMENT DIVISION
38 LAKESIDE AVENUE, WEST ORANGE, N. J.



REC's new literature on temperature and pressure sensors and accessory equipment

If you have anything to do with the accurate measurement of temperatures or pressures, there is information of value to you in this collection of REC technical literature. Check the list below and send for the items that interest you.

	Platinum Temperature Sensors
7617	Immersion Temperature Sensors
	Air Data Sensors
7597	Model 102 Series Total Temperature Probes
126027	Total Temperature Probes
15811	Model 103 Total Temperature Probe
116010	Aerodynamically Compensated and Conventional Pitot Static Tubes
46024	Model 803A Static Pressure Port Calibrator
	Pressure
36010	Model 800 Series Pressure Transducers
46027	Model 802A Reference Pressure Cell
	Accessory Equipment
86012	Triple-Bridge, Multi-Channel Temperature Measurement System
5611	Vibration Isolation Table
7616	Dry Circuit Relay
36113	Mechanical Joint for Applications to Joining Materials of Different Expansion, Bearings which will not freeze at extremely high or low temperatures, rotating seals for extremes of temperature, etc.
	Aeronautical Research
106021	REC Transonic Wind Tunnel Facility and Icing Wind Tunnel Facility
	Technical Bulletins, Preprints
106017	Time Constant and Self-Heating Effect for Temperature Probes in Moving Fluids
116017, Rev. A	Measurement of Mean Temperature in a Duct
7619	Methods of Measuring Temperature Sensor Time Constant and Self-Heating
NY60-91	Temperature Sensing from Aircraft with Immersion Sensors
B. 7.4	Some Recent Developments in Applied Platinum Resistance Thermometry
10605, Rev. B	**Temperature Conversion Chart**
66030	**REC Short Form Catalog**

ROSEMOUNT ENGINEERING COMPANY
4900 West 78th Street, Minneapolis 24, Minnesota

Please send me free the following technical bulletins:

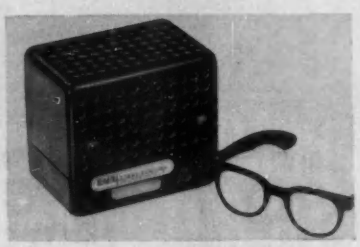
☐ 7617 ☐ 7597 ☐ 126027 ☐ 15811 ☐ 116010 ☐ 46024
☐ 36010 ☐ 46027 ☐ 86012 ☐ 5611 ☐ 7616 ☐ 36113
☐ 106021 ☐ 106017 ☐ 116017 ☐ 7619 ☐ NY60-91 ☐ B. 7.4
☐ 10605 ☐ 66030

Name_____
Company_____ Title_____
Address_____
City_____ State_____

NEW PRODUCTS

to produce automatic program tapes. Transfer of the test configuration is done automatically from the simulator to the punched tape without the need for preparation of a punching chart. Standard unit has an 80-bit configuration and 96 and 120-bit models are available. An eight-level, 10-row keyboard applies a five, six, seven, or eight-level code to the system for checkout or punching of new programs. Price: $1,150.—Electronic Engineering Co. of Calif., Santa Ana, Calif.

Circle No. 316 on reply card



CHARACTER GENERATOR

Said to be the first character generator to combine continuous straight and curved lines to form all digits, letters, and many symbols in a compact solid state package, the Curviline can be used with any CRT display. Writing rates for the full alphanumeric unit of up to 50,000 characters per sec are obtained by forming all symbols from simple formats. Curved lines prevent confusion between similar letters and digits (B and 8, 5 and S, D and 0). The Series C36000, designed for tight spaces, measures 4½ x 6 x 7 in., and sells for $4,500 with character rate of 400–15,000 per sec.—RMS Associates, Inc., Mamaroneck, N. Y.

Circle No. 317 on reply card

RESEARCH, TEST & DEVELOPMENT

TESTS CORES

The Model D constant current flux reset tester has been developed for production testing of tape wound cores for magnetic amplifiers. The compact unit is designed to test cores according to procedures defined by the AIEE (*Transactions* paper No.

REVOLUTIONARY NEW CONCEPT IN RECORDING!



For years instrument users have struggled with making their potentiometer recorders compatable with changing input needs. Today it may be necessary to measure temperature, tomorrow pressure. In order to be prepared to meet these changing demands it has been necessary to stock a number of recorders, or spend hours in modifying existing input circuits.

This costly and outmoded instrumentation is no longer necessary! Westronics, Inc. now brings to the industry a totally new *UNIVERSAL RECORDER* featuring panel or table mounted *EXTERNAL PLUG-IN* input modules. Each has in itself a maximum of versatility.

- **ADJUSTABLE SPAN AND ZERO DIRECTLY CALIBRATED**
  SPAN: 1 to 110 MV Fullscale
  ZERO: ± 50 MV
- **INPUT DIVIDER, 10 STEPS**
  Voltage input to 100 volts
- **THERMOCOUPLE REFERENCE JUNCTION**
  Electronically compensated for 4 commonly used T/C types
- **RESISTANCE BULB BRIDGE**
  May be used with a variety of bulbs DC excited bridge
- **STRAIN GAGE BRIDGE**
  Tare and span adjustment
- **PLUS 20 OTHER FUNCTIONS**

MODERN DESIGN

Everything about the new Westronics Universal Recorder is modern. Nothing old fashioned about this one! Note these features:

- **COMPACT DESIGN (Only 8⅝" high)**
- **ZENER DIODE STANDARDIZATION**
- **PULL OUT CHASSIS**
- **PLUG-IN AMPLIFIERS**
- **BALL POINT PENS (That Really Work!)**
- **QUICK CHANGE CHART SPEED SELECTOR (No gears to change)**

QUALITY

The new Westronics Universal Recorder features a servo system that uses ball bearings throughout. The pen carriage utilizes ball bearing motion on a precision ground track. No troublesome sheet metal parts sliding on rods on this one. Smooth ball bearing floating action is what makes dependable Ball Point inking practical.

VERSATILITY

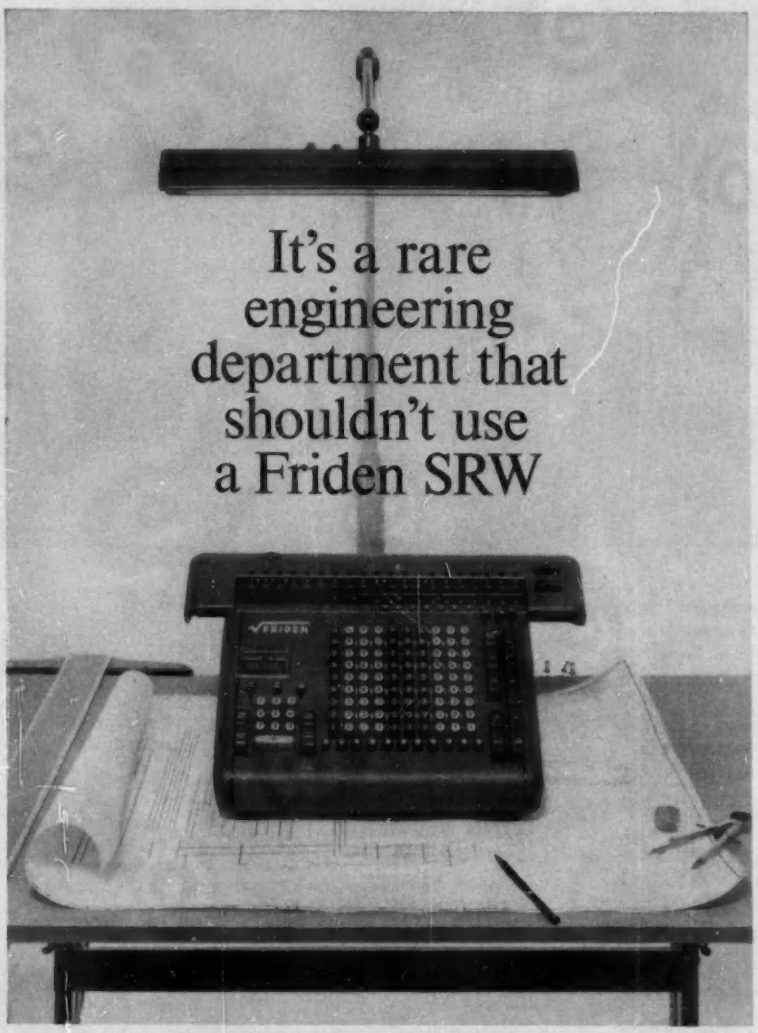
The new Westronics Universal Recorder is second to none in versatility. Available in 5" and 11" strip chart sizes, single pen, 2 pen and multipoints.

ALL THESE FEATURES AND A COMPETITIVE PRICE TOO!

CALL ON ONE OF WESTRONICS 23 SALES-SERVICE REPRESENTATIVES TO HELP YOU SPECIFY A WESTRONICS UNIVERSAL RECORDER TODAY.

westronics, inc.

TWX FT 8248 U • 3605 McCART STREET • FORT WORTH, TEXAS



(Chrysler's missile division uses eleven)

The machine above is the Friden Model SRW Calculator—the only machine of its kind that extracts square roots automatically, at the touch of a key.

Chrysler Corporation's Missile Division bought its first Friden SRW in 1952. They now use 11 SRW's in the planning and development of such missiles as the Jupiter and Redstone.

Chrysler says: *"By reducing the extraction of square roots to a matter of seconds (with accuracy to more than 6 places) the Friden SRW saves many hours of our engineers' valuable time, frees them for more important tasks, helps keep department costs to a minimum."*

Whatever your firm's operation, if you have an engineering department you can make good use of the Friden Square Root Calculator. For more information, see your local Friden Man. Or write: Friden, Inc., San Leandro, Calif.

THIS IS PRACTIMATION: automation so hand-in-hand with practicality, there can be no other word for it.

Friden

Sales, Service and Instruction Throughout the U.S. and World

NEW PRODUCTS

432) at frequencies of 60, 400, and 1,600 cps. Cores to be tested may have a cross-sectional area of from 0.04 to 3.0 cm^2 with minimum lengths of 3.5 to 20 cm at 2 oersteds drive. Standard 115-vac, 60-cps power is required. Magnetics, Inc., Butler, Pa.

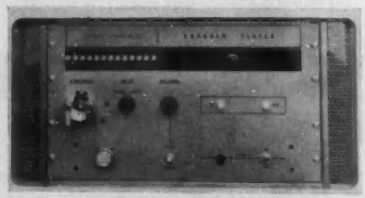
Circle No. 318 on reply card



ANGLE POSITIONER

Designed for applications requiring precise positioning of a rotary component, the CO56402004 is suitable for production line or laboratory service. In a typical application the precise angle positioner would be used in conjunction with a resistance bridge and null detector to measure angular or resolver component accuracy. The instrument features accuracy to within ±3 sec without coupling attachments. A wide range of shaft collets and adapters is available to fit components from Size 8 to Size 37.–Kearfott Div., General Precision, Inc., Little Falls, N. J.

Circle No. 319 on reply card



TESTS SHAFT ENCODERS

This dynamic tester uses self-correlation techniques to evaluate-brushtype V-scan shaft encoders. An internal V-scan selection logic is used to compare consecutive interrogations with each other, instead of with second standard encoders. Testing can be done at variable shaft speeds up to 100 rpm. The testing unit simulates a digital data processor performing V-scan selection on the multiplexed output of several encoders. Outputs can be interrogated periodically or on

AN

2N1015
2N1015A
2N1015B
2N1016
2N1016A
2N1016B



150 Watt

2N1212
2N1208
2N1616
2N1617
2N1618

2N1616A
2N1617A
2N1618A
2N1724



85 Watt

SILICON TRANSISTOR CORP. ADDS 2 NEW SERIES.
THE COMPLETE LINE OF HIGH POWER SILICON TRANSISTORS

The series...
2N1015 **2N1016**
2N1015A **2N1016A**
2N1015B **2N1016B**
are 150 watt single-end stud types. With collector-emitter voltages of 100 volts. Saturation resistance of 0.5 ohms. Minimum beta of 10 at 5 amps.

The series
2N1212 **2N1616**
2N1208 **2N1617**
2N1618
are double-ended 11/16" 85 watt hex stud types.

And...
2N1724 **2N1616A**
2N1617A
2N1618A
are the most popular series in this package, with dramatic improvements from STC.

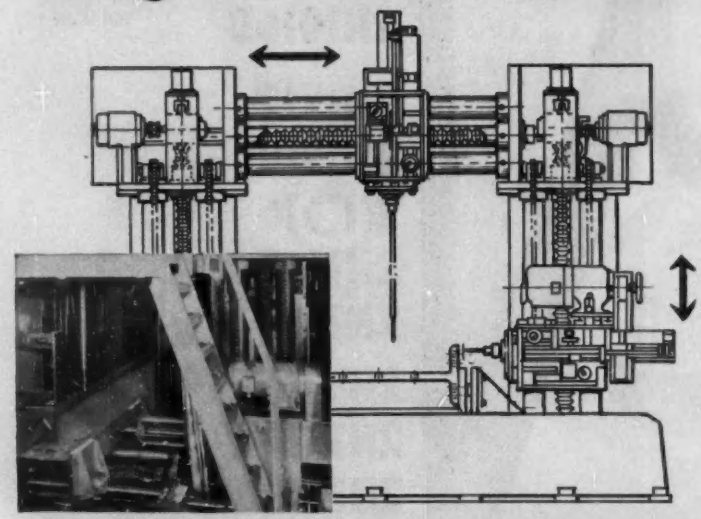
BVCEO of 80 volts. Saturation resistance of 0.5 ohms. Minimum beta of 10 at 5 amps.
Both STC series have the lowest leakage currents in the industry...high temperature stability...low thermal resistance and reliability at full power ratings. Write for Catalog listing complete line of STC's high and intermediate power silicon transistors and silicon diodes.

SILICON TRANSISTOR CORP.

CARLE PLACE, LONG ISLAND, NEW YORK Pioneer 2-4100

CIRCLE 195 ON READER SERVICE CARD 195

Beaver Ball Screws help Mahon save 85% in drilling holes in bridge beams, columns

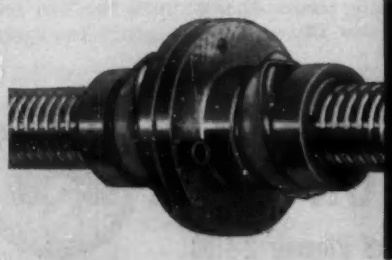


Close tolerance positioning of massive 1½" capacity vertical and horizontal drill heads is accomplished with Beaver ground-thread ball screws in this new, numerically controlled drilling machine, first in the structural steel industry.

Walter P. Hill, Inc., designed and built the machine for The R. C. Mahon Co., Structural Steel Division

In addition to the important drilling cost savings, it offers repeatability in hole pattern accuracy within ±.005" as compared with ±⅛" by conventional methods and eliminates costly hole reaming in final assembly.

If you are considering data control, Beaver ball screws will give you the power efficiency, positioning control and compactness you need. Our engineers will be glad to work with you just as they did, in this case, with the Walter P. Hill designers.

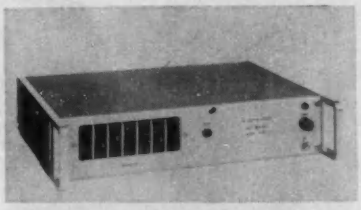


Beaver Precision Products INC.
CLAWSON, MICH.

NEW PRODUCTS

demand. Correlation rate of 6.25 kcps can be regarded as almost continuous.—Guidance and Control Systems Div., Litton Systems, Inc., Woodland, Calif.

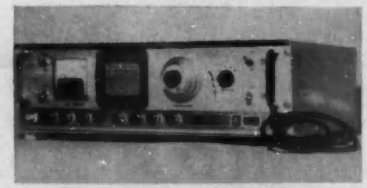
Circle No. 320 on reply card



MEASURES TO 10 NANOSEC

Digital measurements previously unobtainable can now be made with accuracy to within 10 nanosec using a new time interval counter. The model 5275A is suited for precise digital measurement of short intervals between events that can be represented by the proper electrical pulses. Accuracy is available over a full range which extends from 10 nanosec to 0.1 sec. Counted frequency is 100 Mcps, obtained from an external source. — Hewlett-Packard Co., Palo Alto, Calif.

Circle No. 321 on reply card



COMPACT COMPARATOR

Built-in cathode ray tube and precision voltmeter are features of the new IPN-400 volt and phase comparator. Highly accurate measurements of phase shifts and voltage ratios can be made, and the device can be operated as a portable unit. Range is 25 cps to 10 kcps with a measurement accuracy to within ± 0.1 deg; input impedance is 10,000 megohms. Unit takes up only 5¼ in. of panel.—Autonetics, Div. of North American Aviation, Inc., Downey, Calif.

Circle No. 322 on reply card

DIODE TESTER

The Model LT005 high voltage dynamic diode tester allows fast visual

PRODUCTS OF ADVANCED SEMICONDUCTOR TECHNOLOGY...

FAST FIRING—FAST RECOVERY

INTERNATIONAL RECTIFIER SILICON CONTROLLED RECTIFIERS

3, 5, 10 AND 16 AMPERE TYPES

RATED TO 400 VOLTS PRV!



IR SILICON CONTROLLED RECTIFIERS are the remarkable solid-state devices that provide complete control of current turn-on at microsecond switching speeds with no moving parts...no contacts. In the field of high-frequency power conversion they offer a totally new concept for versatile, contemporary circuitry highly efficient in operation... dramatically smaller in size.

THE TABLE BELOW lists the devices now in full production at International Rectifier that feature:

- **Low Gate Currents that Control High Load Currents**
- **Fast Switching Speeds**
- **Low Forward Voltage Drop**
- **Low Forward and Reverse Leakage**

Int'l Type No.	Max. Rep. PRV, Volts	Max. Average Forward Current @ 85°C, Amps	Gate Power, Watts		Max. Forward Voltage Drop @ Rated Current, Volts
			Peak	Average	
3 AMPERE RATED SERIES — 6 TYPES — TEMP. RANGE: −30°C to +105°C					
3RC2 thru 3RC40	25 thru 400	3	5	0.5	1.25
5 AMPERE RATED SERIES — 6 TYPES — TEMP. RANGE: −30°C to +105°C					
5RC2 thru 5RC40	25 thru 400	4.7	5	0.5	1.0
10 AMPERE RATED SERIES — 6 TYPES — TEMP. RANGE: −30°C to +100°C					
10RC2 thru 10RC40	25 thru 400	10	5	0.5	1.25
16 AMPERE RATED SERIES — 6 TYPES — TEMP. RANGE: −30°C to +125°C					
16RC2 thru 16RC40	25 thru 400	16	5	0.5	0.86

For detailed data on all types, request Bulletins SR-350 thru 354.

CIRCLE 197 ON READER SERVICE CARD

Beyond the advanced design opportunities they present, International Rectifier Silicon Controlled Rectifiers possess significant technical advantages: ELECTRICAL CHARACTERISTICS representative of the highest state of the art. MECHANICAL CHARACTERISTICS that provide rugged packages in configurations that have become industry standards...directly interchangeable with other makes. RELIABILITY that stems from two and a half years of continuous refinement of production techniques, test procedures and rigid military quality control programs including the U.S. Army Signal Corps RIQAP plan, a distinguishing mark of quality assurance awarded to International Rectifier for six consecutive years. As a source of supply, International Rectifier extends these benefits: APPLICATION ASSISTANCE without delay from three strategically located engineering groups. DELIVERY from stock on most types...from the factory or from 65 industrial distributors. PRICE AND DELIVERY attractively competitive on both counts...TRY US!

WRITE FOR DETAILS ON HOW YOU MAY OBTAIN SAMPLE SCR's AT NO COST ON THE NEW IR COOPERATIVE SAMPLING PROGRAM!

INTERNATIONAL RECTIFIER CORPORATION:
EL SEGUNDO, CALIF. • PHONE OREGON 8-6281 • CABLE RECTUSA

REGIONAL OFFICES IN NEW YORK CITY, CHICKERING 4-0748 • **FORT LEE,** NEW JERSEY, WINDSOR 7-3311 • **SYRACUSE,** NEW YORK, HEMPSTEAD 7-8405 • **CAMBRIDGE,** MASSACHUSETTS, UNIVERSITY 4-6520 • **ARDMORE,** PENNSYLVANIA, MIDWAY 9-1428 • **SILVER SPRING,** MARYLAND, JUNIPER 9-3305 • **CHICAGO,** ILLINOIS, JUNIPER 3-3095 • **BERKLEY,** MICHIGAN, LINCOLN 8-1144 • **LOS ANGELES,** CALIFORNIA, OREGON 8-6261 • IN CANADA: **TORONTO,** ONTARIO, PLAZA 9-2291

IMMEDIATE OFF-THE-SHELF DELIVERY FROM 65 INDUSTRIAL DISTRIBUTORS THROUGHOUT THE U.S.

INTERNATIONAL RECTIFIER

IOR

SYMBOL OF QUALITY IN SEMICONDUCTORS

FOR YOUR REVIEW...

Four of the Twenty Product lines that comprise

THE INDUSTRY'S WIDEST SEMICONDUCTOR LINE!

SILICON ZENER DIODES—1063 TYPES
Ratings: 250mw to 10w/2.6 to 30 Volts



HIGH VOLTAGE RECTIFIERS—157 TYPES
Ratings: to 440ma/to 16,000 PRV



SILICON POWER RECTIFIERS—107 TYPES
Ratings: to 250 amps/to 600 PRV



SUBMINIATURE GLASS DIODES—40 TYPES
Ratings: to 200ma/to 380 PRV



new from Lear

MINIATURE SERVOS

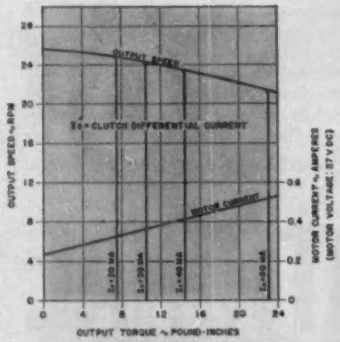
Frequency Response: To 400 cps
Weight: As little as 12 ounces
Torque: From 1 to 73 lb-in

Low control power requirements and zero backlash are achieved with no sacrifice in reliability. The LEAR 3170 series actuators are exceptionally suited for use in . . .

- Computers
- Valve Actuators
- Rocket Nozzle Control
- Missile Flight Control
- Analog-To-Digital Converters

The LEAR 1333 TRANSISTORIZED AMPLIFIER with a 2" x 2½" x 3" envelope, is available for use with the 3170 actuator. The integral power supply requires only 115 VAC for excitation. The LEAR 4514 System, consisting of the 3170 actuators and the 1333 amplifier is AVAILABLE NOW.

Write for Data Sheet 111-14 for further performance information.



PERFORMANCE CURVE

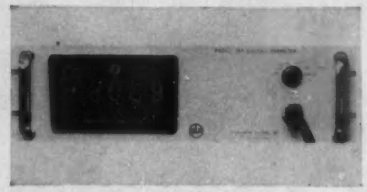


LEAR

ELECTRO-MECHANICAL DIVISION
110 IONIA AVENUE, N.W., GRAND RAPIDS 2, MICHIGAN

monitoring and testing of reverse characteristics of germanium or silicon diodes. Accuracy is to within ± 5 percent with negligible drift after warmup. Voltage sensitivity is 5-200 volt per cm; current sensitivity 10-500 microamp per cm. Maximum voltage is 2,000 volts; maximum current is 0.3 ma. Unit measures 16¾ x 21½ x 19½ in. (h, w, d).—Micromodular Components Div., Ling-Temco-Vought, Inc., Anaheim, Calif.

Circle No. 323 on reply card

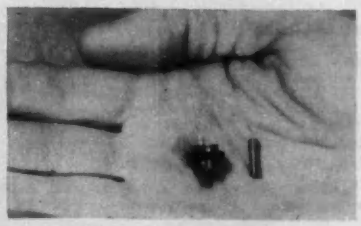


DIGITAL OHMETER

Newest addition to this manufacturer's line of low-cost industrial digital measuring instruments, the NLS-784 includes printout connection at a price of $1,650. The meter is fully automatic, with automatic range changing, positioning of the decimal point, and built-in controls for automatic operation of data printers. For troubleshooting and servicing, the device features plug-in stepping switches and circuit boards and snapout readouts for fast lamp changing. Accuracy is to within ± 0.05 percent, plus 1 digit; range is from 0.1 ohm to 10 megohms.—Non-Linear Systems Inc., Del Mar, Calif.

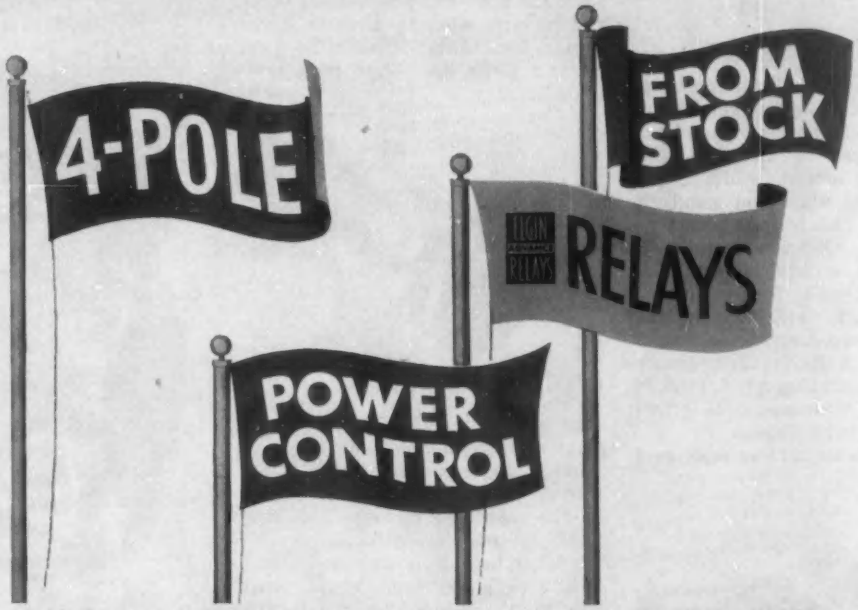
Circle No. 324 on reply card

PRIMARY ELEMENTS & TRANSDUCERS



CRYOGENIC SENSORS

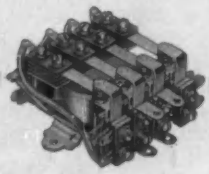
Only about the size of a five-cent piece, these two cryogenic sensors ac-



4-POLE POWER CONTROL RELAYS FROM STOCK

Elgin Advance stocks the only 4-pole power control relay of this type on the market. Specify the PC Series when you require dependable current switching.

The PC Series features heavy load carrying capacity, combined with small size—a variety of contact arrangements—and a wide range of AC and DC coil voltages and resistances.

another example of  **reliable relayability**

SPECIFICATIONS

Contact arrangements—SPDT, DPDT, 3PDT, 4PDT
Contact rating—15 amps resistive; 5 amps inductive
Contact material—0.25″ dia fine silver
Coil voltages & resistances—wide range of AC and DC
AC power—10-12 VA, nominal
DC power—2-3 watts, nominal
Dimensions—1.906″ x 3.062″ x 2.593″, maximum
Weight—8 ounces, maximum

send for  **latest data**

ELGIN advance RELAYS

THE ELECTRONICS DIVISION OF ELGIN NATIONAL WATCH COMPANY
2435 NORTH NAOMI STREET, BURBANK, CALIFORNIA

CIRCLE 199 ON READER SERVICE CARD 199

curately measure temperatures to as low as 4 deg K. The tiny germanium devices are designed for test and operational phases of space vehicles using liquid helium and nitrogen and for use in calibration and standards laboratories. Total temperature range is 4-40 deg K. One of the sensors is for measuring surface temperatures; the other is a probe for internal application. Both are hermetically sealed. The sensors can be used with conventional millivolt instruments. Price: $200 (uncalibrated).—Primary Sensors Dept., Minneapolis-Honeywell Regulator Co., Philadelphia, Pa.

Circle No. 325 on reply card



U-SCAN ENCODER

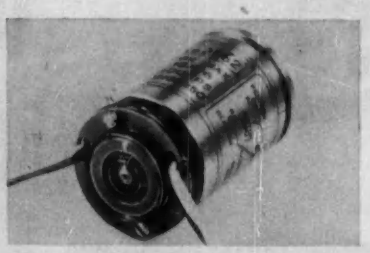
A new U-scan technique is used in this analog to digital shaft position encoder. The CG-733 Series is said to incorporate the advantages of self-selection V-scan encoders but eliminate their disadvantages. Design simplicity assures reliability. Internal diodes have been eliminated so there is no drop in output levels from bit to bit. Except for small bistable drive circuit, brush selection logic is performed within the disc design. Only half the number of brushes needed in a V-scan encoder is needed where digital information only is required. Units measure 1.75 in. in diam and, depending on output counts, from 1.6 to 3.5 in. long and weigh 5-11 oz. Outputs of 128, 8,192, and 524,288 are available with an accuracy to within ±1.—Datex Corp., Monrovia, Calif.

Circle No. 326 on reply card

ELECTRO-OPTICAL POT

This new potentiometer, tradenamed Betapot, uses a light beam for pickoff. The friction of mechanical wiping action is eliminated by beaming a stream of light through a thin film of photoconductive semiconductor material. Infinite resolution is possible and there is no contact noise, since the pot's resistive element need not be wire wound.—Duncan Electronics, Inc., Costa Mesa, Calif.

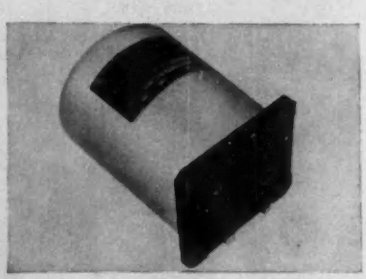
Circle No. 327 on reply card



FULL-VIEW SYNCHROS

This line of Size 8 synchros incorporates transparent end caps for easier marking of electrical zero points. The units contain electrical zero marks on the rear collector ring and the back side of the brush block, permitting users to observe and mark electrical zero points more easily than with most synchros. In the latter, shaft end observation cannot be conveniently made. Size 11 models are also available.—IMC Magnetics Corp., Western Div., Maywood, Calif.

Circle No. 328 on reply card



LAB STANDARD

Said to have the accuracy of a mercury manometer, this portable laboratory pressure standard requires no daily maintenance and provides a direct voltage output. The Model 451287 uses a new capsule element to actuate a precision potentiometer. Output can be read on a digital ratio meter or used to drive a servo readout device directly. Over-all accuracy is 0.010 in.Hg over a pressure range from 0 to 31.5 in gage, absolute, and differential models.—Giannini Controls Corp., Duarte, Calif.

Circle No. 329 on reply card

PLUS . . .

(330) Greater economies in the design of photodiode readout circuitry for EDP equipment are possible using



for

RCA Computer Switching Devices

"STOP"

CALL YOUR RCA SEMICONDUCTOR DISTRIBUTOR

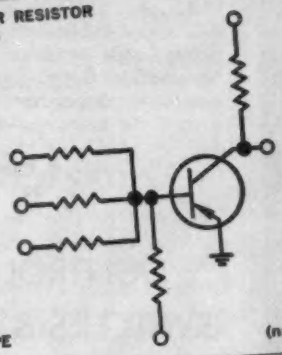
For a comprehensive line of superior-quality RCA Transistors and Silicon Rectifiers, and all RCA Semiconductors for special projects or pre-production requirements...call your RCA Semiconductor Distributor. Just check the extra advantages he offers you:

- **Fast delivery from local stock**
- **Prompt delivery of the latest RCA types for your evaluation**
- **Orders filled from factory-fresh stock**
- **Up-to-date, practical product information**
- **Valuable RCA technical assistance when you need it**
- **"One-stop" service on your orders**
- **Specialists who understand your problems and your electronic needs.**

Remember, when *you* want fast delivery, reliable service, always check first with your local RCA Semiconductor Distributor. For the name and address of your nearest RCA Semiconductor Distributor, write RCA, Distributor Products Sales, Harrison, N. J.

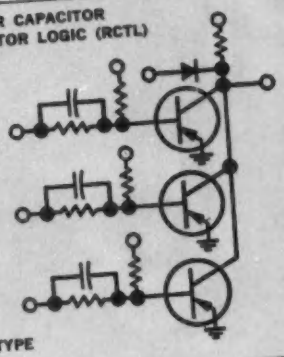
ACHIEVE STAGE DELAYS AS LOW AS 1 NANOSECOND... CLOCK RATES FROM 1 TO 1,000 Mc WITH RCA'S BROAD LINE OF COMPUTER SWITCHING DEVICES

TRANSISTOR RESISTOR LOGIC (TRL)



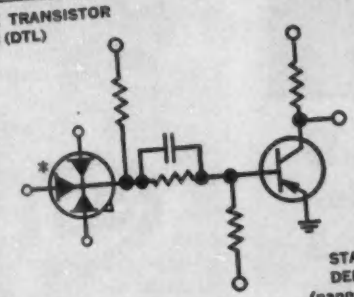
RCA TYPE	STAGE DELAY (nanosec)
2N585 (NPN ALLOY)	1000
2N404 (PNP ALLOY)	800
2N1301, 2N795 (PNP MESA)	200
2N697 (NPN SILICON)	175
2N705 (PNP MESA)	100
2N706 (NPN SILICON)	100
TA-1882 (NPN UHF MESA)	60

RESISTOR CAPACITOR TRANSISTOR LOGIC (RCTL)



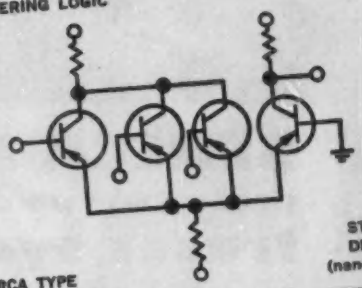
RCA TYPE	STAGE DELAY (nanosec)
2N585 (NPN ALLOY)	200
2N404 (PNP ALLOY)	160
2N1301, 2N795 (PNP MESA)	40
2N697 (NPN SILICON)	35
2N705 (PNP MESA)	13
2N706 (NPN SILICON)	22
TA-1882 (NPN UHF MESA)	9

DIODE TRANSISTOR LOGIC (DTL)



RCA TYPE	STAGE DELAY (nanosec)
2N585 (NPN ALLOY)	240
2N404 (PNP ALLOY)	180
2N1301, 2N795 (PNP MESA)	50
2N644, 2N1450 (PNP DRIFT-FIELD)	—
2N697 (NPN SILICON)	40
2N705 (PNP MESA)	16
2N706 (NPN SILICON)	27
TA-1882 (NPN UHF MESA)	12

TRANSISTOR CURRENT STEERING LOGIC



RCA TYPE	STAGE DELAY (nanosec)
2N585 (NPN ALLOY)	120
2N404 (PNP ALLOY)	100
2N1301, 2N795 (PNP MESA)	30
2N644, 2N1450 (PNP DRIFT-FIELD)	17
2N697 (NPN SILICON)	25
2N705 (PNP MESA)	12
2N706 (NPN SILICON)	15
TA-1882 (NPN UHF MESA)	7

1N3128 to 1N3130, RCA Tunnel Diodes—Stage Delays in Tunnel Diode Logic Circuit of 5 nanosec. to 1 nanosec.

*3DG001 (Multiple-Diode Switch)

Now, over 50 RCA silicon and germanium switching devices provide comprehensive coverage of your logic-circuit needs for military and industrial data-processing equipment.

This broad spectrum of RCA switching transistors and diodes can bring flexibility and economy to your new logic-circuit designs. In the practical working circuits shown, these devices can help you meet and exceed many of the exacting speed requirements of today's military and industrial computers.

Here are some of the outstanding features of these versatile switching devices:

- RCA 3907/2N404...*Extra rugged and reliable*...Produced under RCA's Certified-Reliability Premium Switching-Transistor Program.
- RCA 2N585...Germanium NPN counterpart of the 2N404.
- RCA 2N1301...High-speed germanium switching mesa transistor in TO-5 package...minimum beta of 40, pulse repetition rates up to 10 Mc.
- RCA 2N697...High-speed, high-current silicon *planar* transistor.
- RCA 2N705...Very high-speed germanium switching mesa type.
- RCA 2N706...Very high-speed silicon *planar* switching transistor designed to meet MIL specifications.
- RCA Developmental Type TA-1882...*World's fastest* germanium mesa transistor.
- NEW RCA 2DG001, 3DG001...Multiple arrays of two and three diffused-junction germanium computer switching diodes in TO-33 package size. Typical recovery time 160 nanoseconds.

Call your RCA representative today for further information. For additional technical data, write RCA Semiconductor and Materials Division, Commercial Engineering, Section I-56-NN, Somerville, N.J.

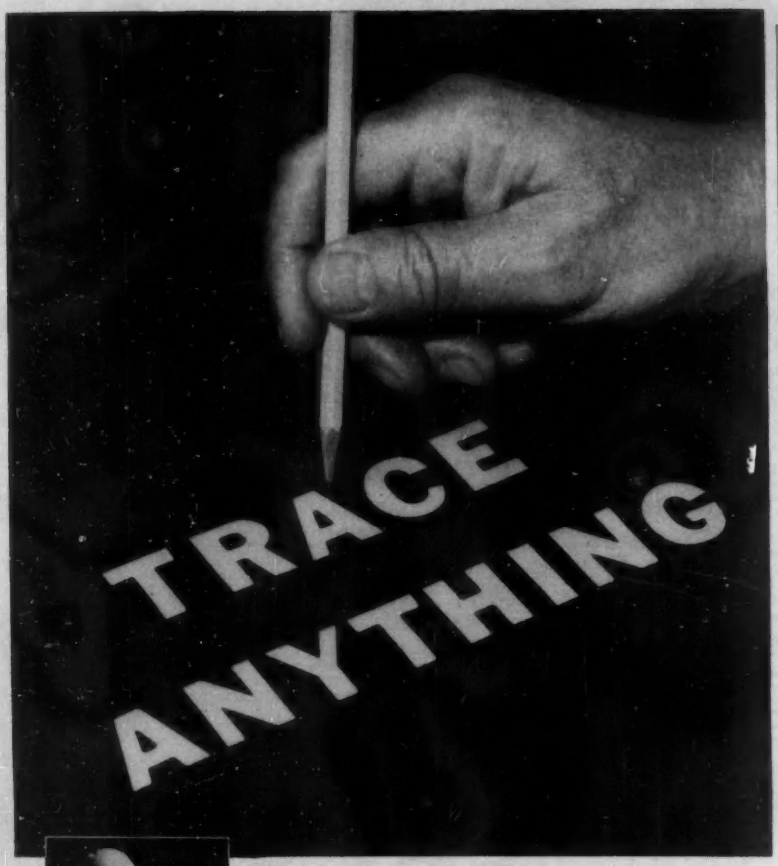
Available Through Your RCA Distributor

RCA

The Most Trusted Name in Electronics

RADIO CORPORATION OF AMERICA

CIRCLE 201 ON READER SERVICE CARD





SENECA FALLS
single and two dimension
tracer systems

Seneca Falls offers two simplified, moderate-cost electromechanical tracer systems which will accept tape, template or dial input signals and automatically machine simple or difficult contours in any material that is machineable. Each has unique advantages not found in conventional tracer systems. Both systems have demonstrated their dependability and ease of maintenance in various rugged industrial applications.

These tracer systems are but two of many outstanding control systems and control components developed, designed and perfected in our Electronic Laboratories.

Bulletin EE1010 describes the tracer systems. Write for it, and if you have *any* control problem, give us the facts.

SENECA FALLS MACHINE
PIONEERS IN AUTOMATION

ELECTRONICS DIVISION

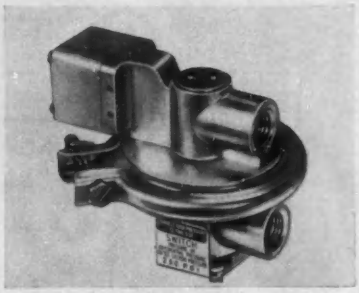
SENECA FALLS MACHINE CO., SENECA FALLS, N. Y.

NEW PRODUCTS

the new line of silicon **photosensors** made available by **Philco Corp., Lansdale Div.**, Lansdale, Pa., at a price of $5-12. . . . (331) A line of hermetically sealed inductance and reluctance **pickup coils** available from **Potter Aeronautical Corp.**, Union, N. J., is suitable for direct exposure to temperature in the range of −450 to +1,150 deg F.

Circle No. 330 or 331 on reply card

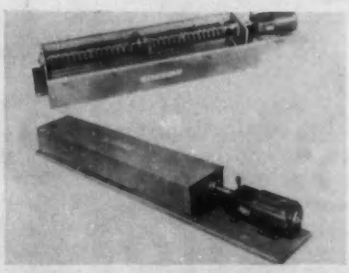
CONTROLLERS, SWITCHES & RELAYS



SENSITIVE SWITCHES

These spring-biased diaphragm switches are sensitive enough to sense pressures and differential pressures in the range of 0.25 to 16 in. of water. Desired actuation pressure is set by a direct reading dial. No mechanical linkages are used, and the units cannot be damaged from overpressure up to rated capacity of 250 psi. The switches have been tested for frequencies to 2,000 cps. Price: $40-90.—Pall Corp., Glen Cove, N. Y.

Circle No. 332 on reply card



ADJUSTABLE SEQUENCING

Precision adjustment of up to 30 circuits through the use of easily set

split lobe cams is possible with this new sequencing programmer. Continuous range of open and closed contacts can be obtained from 8 to 352 deg revolution of the input shaft. Speed variations from 0 to 150 rpm are possible with the adjustable motor drive. Snap-action spdt switches are used and are rated at 5 amp, 440 vac or 10 amp, 220 vac or 15 amp, 115 vac. Price: about $1,000.—Gemco Electric Co., Detroit, Mich.

Circle No. 333 on reply card

RUGGED BUT SENSITIVE

This highly sensitive relay uses solid state circuitry to guarantee high resistance to vibration and shock. The Magsense converter's single setpoint is easily adjustable with accuracy and repeatability within 1 microamp over full input range. Signal input range of 0 to 100 microamp can be extended with no loss in resolution. Output is the solid state equivalent of a spdt switch rated at 1 amp at the dc line voltage.—Daystrom, Inc., Control Systems Div., La Jolla, Calif.

Circle No. 334 on reply card



TINY PRESSURE SWITCHES

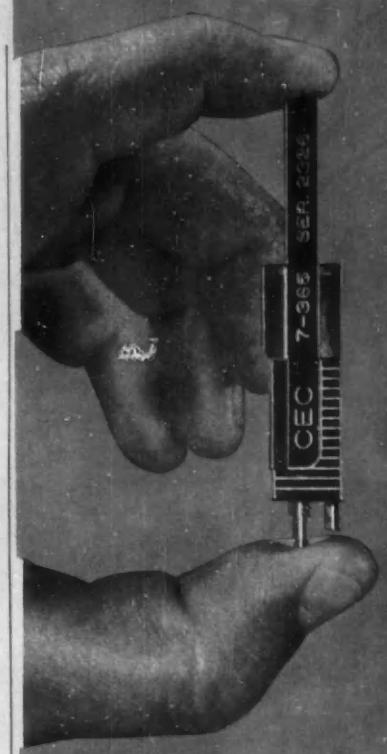
This subminiature pressure switch is designed to withstand 50-g shock, 15-g vibration, and 200 percent overpressure. The device can be set in the field over a limited range: ± 10 psig. Accuracy is to within ± 2 psig with repeatability to 0.5 psig. The spst switch is rated at 0.2 amp resistive at 28 vdc or 115 vac. The Model 6289 weighs just 1.5 oz and measures 3¼ in. by ¾ in. in diam.—Aero Mechanism, Inc., Van Nuys, Calif.

Circle No. 335 on reply card

RUGGED LEVEL CONTROL

Designed for high reliability, this ultrasonic liquid-level control uses a solid state switch and operates in high shock and vibration environments as exist aboard silo-launched missiles.

CIRCLE 203 ON READER SERVICE CARD→



NOW . . . A RECORDING GALVANOMETER WITH A NATURAL FREQUENCY OF 13 KC vastly extending the range of high frequency data recording in oscillography

You're looking at CEC's Type 7-365 High Frequency Galvanometer, an instrument with a sensitivity of 69 ma/inch and the ability to deflect ±1⅛ inch.

The 7-365, newest in Consolidated's high-performance galvanometer line, is an extension of Type 7-300 series high performance galvanometers—and it's compatible with all CEC oscillographs. A look at the specifications for Type 7-365 will tell you why this new galvo permits the recording of high frequency data never before possible in oscillography. Here are some of its outstanding features:

Undamped natural frequency:	13,000 cps
Optical arm:	11.5 inch
Safe current:	80 ma Vector
Maximum non-linearity at ±1" peak amplitude:	1%
External damping:	500 ohms

For complete information, call your nearest CEC sales and service office or write for Bulletin CEC 7365-X1.

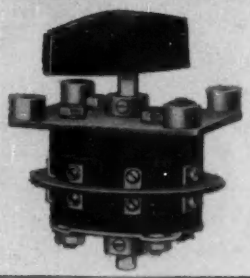
Transducer Division CEC

CONSOLIDATED ELECTRODYNAMICS / pasadena, california

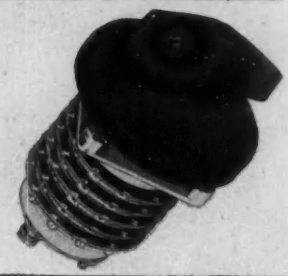
A SUBSIDIARY OF Bell & Howell · FINER PRODUCTS THROUGH IMAGINATION

8-12-16 POSITION
ROTARY SWITCHES
for industrial and military applications

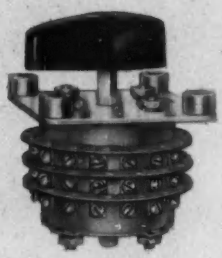
8 POSITION TYPE JR



12 POSITION TYPE JM



16 POSITION TYPE JK



Type	Sections	Positions	Poles	Contacts	Indexing	Mounting	Electrical Ratings interrupting
JR	1 to 30	2 to 8	1 to 60	non-shorting or shorting	45°	panel	10a., 125v. a-c & 28v. d-c 5a., 240v. a-c & 125v. d-c
JM	1 to 25	2 to 12	1 to 75	non-shorting or shorting	30°	panel	7..5 amp., 125 volts a-c
JK	1 to 10	2 to 16	1 to 10	non-shorting or shorting	22½°	panel	5 amp., 125 volts a-c

These three types of ESCO rotary switches are standard items designed, manufactured, and tested to meet required environmental conditions. Special switches can be assembled, from standard parts, to meet your control requirements.

Because of the many different multi-contact assemblages possible, ESCO rotary switches can control the most complex electric circuits.

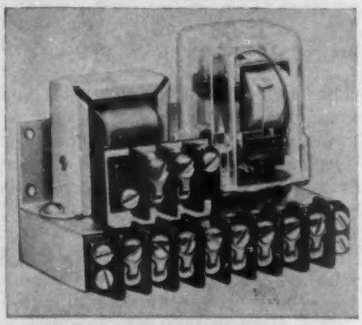
Write for catalog containing complete details.

ESCO of WEYMOUTH
ELECTRO SWITCH CORP.
Weymouth (Boston 88), Massachusetts

NEW PRODUCTS

Response time can be factory adjusted from 2 to 20 millisec. Input voltage is 28 vdc; output current with sensor loaded is less than 10 microamp and with sensor unloaded, 1 amp. Resolution is to 0.22 in.—Acoustica Associates, Inc., Los Angeles, Calif.

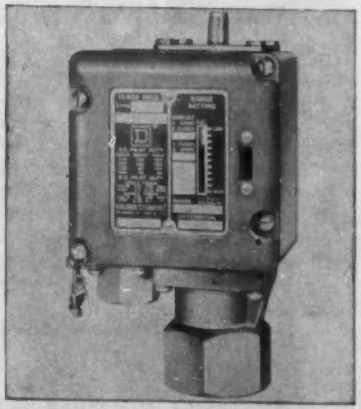
Circle No. 336 on reply card



PE SCANNER RELAY

This simple, compact PE-1 photoelectric scanner provides positive response on light beam interruption without the use of tubes or transistors. The power-type photocell used has high infrared sensitivity and a filter to minimize ambient visible light effects. The cell operates a dc amplifier at up to 500 counts per min. The relay is a plug-in unit with two sets of spst load contacts, one NO and one NC. Contacts are rated at 8 amp, 115 vac, noninductive.—Fanner Electric Products Co., Inc., Newton Lower Falls, Mass.

Circle No. 337 on reply card

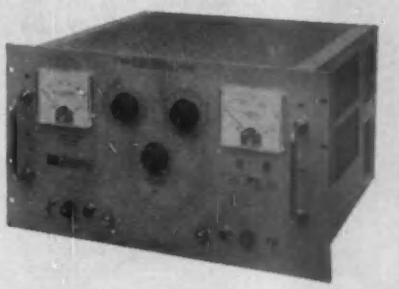


WIDE RANGE SWITCH

This new hydraulic pressure switch operates on a wide range of pressures, adjustable from 2,000 to 15,000 psi on

HOLD IT!

THERE'S NO SUBSTITUTE FOR AN ELECTRONIC MEASUREMENTS CONSTANT-CURRENT POWER SUPPLY



what every engineer knows about constant-current power supplies . . .

How do you check the peak inverse voltage rating of a solid state junction? the breakdown voltage of a reference diode at a specified current? the dynamic impedance of a reference diode? and the many other parameters that are so easily checked with constant-current power supplies?

It's an easy matter to convert some voltage-regulated power supplies to current-regulated operation. At least it's easy with an E/M® Regatron Programmable Power Supply. But for true constant-current performance, there's no substitute for a power supply specifically designed for constant-current operation.

Take Electronic Measurements' Model C638A shown here. It's an easy matter to set the current control to any value desired—from a few microamperes up to 100 ma—manually or programmably. And there's no juggling with makeshift, extra circuity. Then you can adjust the voltage compliance to any value from 0 to 1500 V. There's no fear that the voltage may be too great or not enough; the voltage control sets the upper limit.

Here are some additional features of the C638A: Output impedance is 10^4 megohms at 0.5 μa to 0.5 megohms at 100 ma. Above 2.2 μa, regulation is better than 0.15%, line or load, Ripple is less than 0.01%+ 1 μa rms. A modulation input is provided.

But to get back to the point; to check the peak inverse voltage rating of a solid state junction, simply set the output current control of an E/M Constant-Current Power Supply at the specified current. Connect the output to the junction, turn the power supply on, and measure the voltage drop across the junction. What could be easier? And other measurements can be made almost as easily.

For a complete discussion of constant-current power supplies with ratings up to 1A, ask for Specification Sheet 3072B. It lists all the models and specifications, too.

®Registered U. S. Patent Office. Patents Issued and Pending.

ELECTRONIC MEASUREMENTS COMPANY, INCORPORATED
EATONTOWN • NEW JERSEY

rising pressure. The unit has oil-tight construction with a rugged piston, long life switching member, and range-locking nut. Switch is two-pole snap-action type and is capable of operating at up to 300 times per min. A provision for strain relief protects the units from shock or pressure surges.—Square D Co., Asheville, N. C.

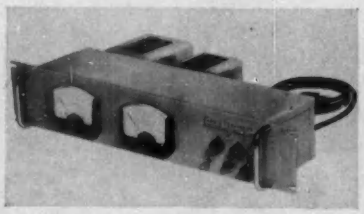
Circle No. 338 on reply card

PLUS . . .

(339) **Electronics Div., Elgin National Watch Co.,** Burbank, Calif., has made available a SP Series of **sensitive dc relays** priced at $3, which will operate on just 100 mw. . . . (340) A heavy duty 10-amp relay is available as a feature of the L-400 Series rotary paddle **material level control** from **Flo-Tronics, Inc., Electronics Control Div.,** Minneapolis, Minn. . . . (341) The new M-250 relay from **Leach Corp.,** Los Angeles, Calif., weighs only 0.35 oz, and is half the size of a standard crystal can.

Circle Nos. 339, 340 or 341 on reply card

POWER SUPPLIES



MODULAR LINE

Two units in a new line of modular power supplies are shown above mounted in a rack panel, complete with meters. One, two, or three isolated outputs can be provided on a single panel. Input voltage range is 105-125 volts, 40-400 cps. Regulation is to within ± 0.5, with models regulated to ± 0.05 percent available. Ripple is less than 10 mv on regular models and less than 1 mv rms on the more highly regulated units. Output currents available are from 50 ma to 12 amp; voltages are from 2.8 to 52 volts. Prices range from $50 to $345.—Technipower, Inc., S. Norwalk, Conn.

Circle No. 342 on reply card

ALL SILICON SUPPLY

This new Model PS4241 M supply uses all silicon semiconductor circuitry. Using convection cooling, it can operate at 71 deg C ambient. Dc output is 245-255 volts at 0-200 ma. Ac input required is 105-125 volts, 50-63 cps. Line regulation is to within less than 0.05 percent for the above ac variation. Load regulation is to within less than 0.1 percent for load changes from zero to full. Ripple and noise are less than 5 mv rms. The unit is 5¼ in. high by 15 in deep and fits standard racks. Price: $695.—Power Sources, Inc., Burlington, Mass.

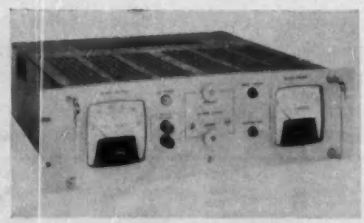
Circle No. 343 on reply card



FOR PRODUCTION TESTING

Continuously variable output of 0-120 volts, either ac or dc, is provided by this versatile new power unit. Maximum load current is 5 amp at 120 volts with ripple held to less than 2 percent at maximum dc voltage and current. Ac regulation is to within less than 5 percent from no load to full load. The bench-top device is designed for production testing of ac-dc equipment, such as motors and relays, and can be used as a power supply for vacuum tubes and transistors because of its low ripple, broad voltage range, and high power. Nominal input is 120 volts, 60 cps.—Surface-Air Electronics Co., El Segundo, Calif.

Circle No. 344 on reply card



SUPPLY LOW VOLTAGES

This line of rack mounted, low voltage transistorized units is designed for applications involving equipment operation and secondary battery charging. Four categories of the trans-



for
RCA SILICON RECTIFIERS
"STOP"

CALL YOUR RCA SEMICONDUCTOR DISTRIBUTOR

For a comprehensive line of superior-quality RCA Transistors and Silicon Rectifiers, and all RCA Semiconductors for special projects or pre-production requirements...call your RCA Semiconductor Distributor. Just check the extra advantages he offers you:

- **Fast delivery from local stock**
- **Prompt delivery of the latest RCA types for your evaluation**
- **Orders filled from factory-fresh stock**
- **Up-to-date, practical product information**
- **Valuable RCA technical assistance when you need it**
- **"One-stop" service on your orders**
- **Specialists who understand your problems and your electronic needs.**

Remember, when *you* want fast delivery, reliable service, always check first with your local RCA Semiconductor Distributor. For the name and address of your nearest RCA Semiconductor Distributor, write RCA, Distributor Products Sales, Harrison, N. J.

RCA ANNOUNCES

New High-Voltage Silicon Rectifiers covering the full range from 1,200 to 10,000 PIV



10 RCA Diffused-Junction rectifiers with integral voltage-equalizing networks offer outputs up to 825 ma DC for military and industrial applications

Here's important new flexibility for your critical high-voltage rectifier applications—RCA's broad line of encapsulated, insulated multi-cell rectifiers. Check the benefits these rectifiers can bring to your designs:

- Integral voltage equalization—Resistor-capacitor equalization network across each internal rectifier cell equalizes voltage distribution under both transient and steady-state conditions.
- Ratings you can use with confidence—RCA rectifiers are designed to provide top performance at maximum published ratings. Conservative RCA ratings provide built-in safety factor.
- High output current:
  - —550 to 825 ma at 60°C. Single-phase, half-wave circuit.
  - —Up to 2.2 amps.—6 rectifiers in 3-phase full-wave bridge circuit.
  - —Up to 1.65 amps.—4 rectifiers in single-phase full-wave bridge circuit.
- High efficiency and excellent regulation—Each diffused-junction cell has only 0.6-volt maximum voltage drop (full cycle average).
- Wide operating and storage temperature range. —65°C to +125°C.
- Compact Size—2⅜ to 5½ cubic inches.
- Unique case design—allows rugged mounting; provides extra long corona path for added safety.
- Designed to meet military mechanical and environmental test specifications.

HALF-WAVE RECTIFIER SERVICE

Absolute-Maximum Ratings for Supply Frequency of 60 cps, Single-Phase Operation, and with Resistive or Inductive Load.

	CR101	CR102	CR103	CR104	CR105	CR106	CR107	CR108	CR109	CR110
Peak Inverse Volts	1200	2000	3000	4000	5000	6000	7000	8000	9000	10000
RMS Supply Volts	840	1400	2100	2800	3500	4200	4900	5600	6300	7000
DC Blocking Volts	1200	2000	3000	4000	5000	6000	7000	8000	9000	10000
Average Forward Milliamperes: At 60°C ambient temperature	825	825	715	605	605	550	550	550	550	550
At 100°C ambient temperature	320	320	275	235	235	210	210	210	210	210
Peak Recurrent Amperes	5									
Peak Surge Amperes: (One-half cycle, sine wave)	18									
Ambient Temperature Range: Operating and storage	−65 to +125 °C									

- "CR"-Series types may be used in series up to 20,000 PIV without added voltage equalization.

Custom designs are available for higher voltages, higher temperature, oil submersion, special packaging requirements.

Call your RCA REPRESENTATIVE today for full particulars on these 10 new rectifiers. For additional technical information, write RCA Semiconductor and Materials Division, Commercial Engineering, Section I-56-NN, Somerville, N. J.

AVAILABLE THROUGH YOUR RCA DISTRIBUTOR

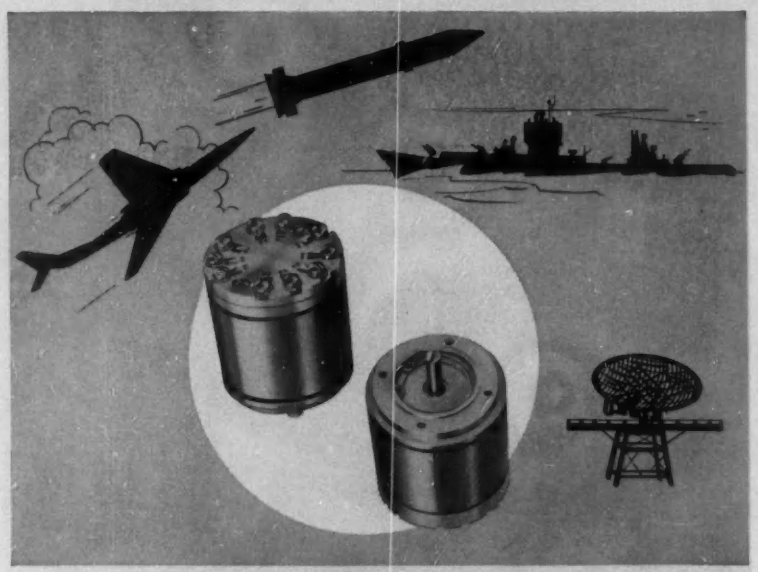
The Most Trusted Name in Electronics
RADIO CORPORATION OF AMERICA

RCA FIELD OFFICES...EAST: Newark, N. J., 744 Broad St., HUmboldt 5-3900 • (Camden, N. J. area) Brlton, N. J., 605 Marlton Pike, HAzel 8-4802 • Syracuse, N. Y., 731 James St., Room 402, GRanite 4-5591 • Baltimore, Md., ENterprise 9-1850 • NORTHEAST: Needham Heights 94, Mass., 64 "A" St., Hillcrest 4-7200 • SOUTHEAST: Orlando, Fla., 1520 Edgewater Drive, Suite #1, GArden 4-4768 • EAST CENTRAL: Detroit 2, Mich., 714 New Center Bldg., TRinity 5-5600 • CENTRAL: Chicago, Ill., Suite 1154, Merchandise Mart Plaza, Whitehall 4-2900 • Minneapolis, Minn., 5805 Excelsior Blvd., WEst 9-0676 • WEST: Los Angeles 54, Calif., Box 54074, RAymond 3-8361 • (San Francisco area) Burlingame, Calif., 1838 El Camino Real, OXford 7-1620 • SOUTHWEST: Dallas 7, Texas, 7905 Carpenter Freeway, Fleetwood 7-8167 • GOV'T: Dayton, Ohio, 224 N. Wilkinson St., BA 6-2366 • Washington, D. C., 1725 "K" St., N.W., FEderal 7-8500.

CIRCLE 207 ON READER SERVICE CARD



ENGINEERING
REPORT
ON BENDIX COMPONENTS



Now available in production volume:

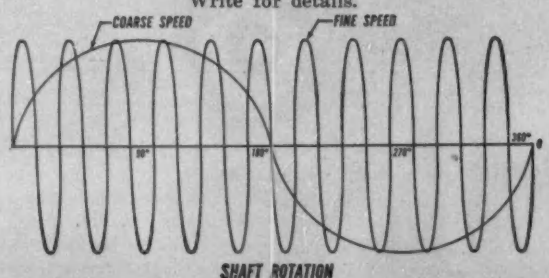
BENDIX AUTOSYN® SYNCHROS AND SYSTEMS with 30-SECOND ACCURACY

The Bendix two-speed Autosyn synchro was developed to meet the need for accurate data transmission with maximum system simplicity. Two electrical outputs are produced from the Autosyn single shaft, eliminating both inaccuracies of two-speed gearing and the installation and maintenance costs of an additional unit.

Autosyn units can be supplied with leads or terminal boards. Units can be used back-to-back or can be coupled with mechanical two-speed transmitters or control transformers. They measure only 2.34" in length by 1.75" in diameter.

Other features: **Accuracy unaffected by thermal or mechanical stress—Adaptability to gyro pick-off—Elimination of gear error of mechanical two-speed system—High signal-to-null ratio.**

Write for details.



SHAFT ROTATION

EXAMPLES OF APPLICATIONS: Fire Control Systems—Navigation Computers—Inertial Guidance Systems—Radar Antenna Tracking

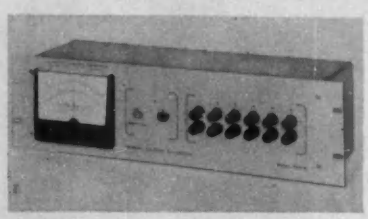
Eclipse-Pioneer Division
Teterboro, N. J.

Bendix

District Offices: Burbank, and San Francisco, Calif.; Seattle, Wash.; Dayton, Ohio; and Washington, D. C.
Export Sales & Service: Bendix International, 205 E. 42nd St., New York 17, N. Y.

istorized supplies with these outputs are offered: 4.5 vdc, 5 amp; 4.5 vdc, 10 amp; 30 vdc, 5 amp; 4.5 vdc, 10 amp for battery charging. All operate from 115 vac, 60 cps.—Arnoux Corp., Los Angeles, Calif.

Circle No. 345 on reply card



GUARANTEED STABLE

This solid state primary voltage reference has a guaranteed stability of 2 parts per million in 3 months and 3 parts per million in a year. The Zener diode device has a calibration accuracy to within 0.0015 percent. Tests have shown that the stability of the new unit may be better than that of a temperature controlled saturated cell. Price: $3,850.—Calibration Standards Corp., Alhambra, Calif.

Circle No. 346 on reply card

STANDBY SUPPLY

This new static standby power supply provides precisely controlled 60-cps power when line supply fails. Starting is instantaneous, so there is not even a momentary interruption in system operation. Connection to the ac power line is the only installation required, as a static charger and battery in combination with the inverter chassis are supplied. Output is 2.5 kva, 1 phase, 115 volts ± ½ volt. —Tapco Div., Thompson Ramo Woolridge, Inc., Cleveland, Ohio.

Circle No. 347 on reply card

ACTUATORS & FINAL CONTROL ELEMENTS

SMALL CURRENT DRAW

This new rotary solenoid requires less operating current than a transistor and produces a torque of 0.005 oz-in.

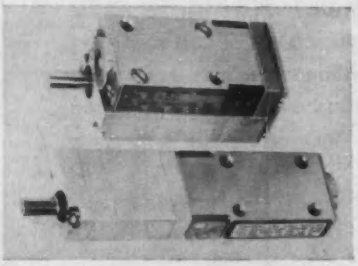
min. The Type 9931-04 requires just 0.0033 amp input current at room temperatures and 0.005 amp max at 20 vdc and −55 deg C. Voltage range is 25-20 vdc. Total rotation is 35 deg.–John Oster Mfg. Co., Avionic Div., Racine, Wis.

Circle No. 348 on reply card

OIL FILLED TIMER

This synchronous timer motor uses a unique method of sealing all moving parts in oil to get noiseless and long life operation. A special spring loaded packing gland prevents oil from working out of the housing during operation. It is said to be one of the smallest timer motors available. The unit has an outside diameter of 1 11/16 in., ¼ in. smaller than conventional synchronous motors.–Lake City, Inc., Sub. of Controls Co. of America, Crystal Lake, Ill.

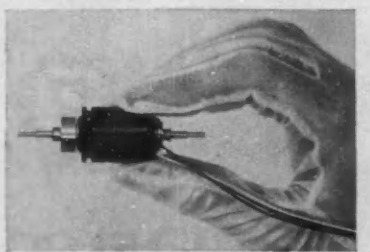
Circle No. 349 on reply card



TINY GEARMOTORS

Continuous duty torque ratings of as high as 35 oz-in. are available in a new line of gearmotors having a frontal area as small as 0.4 sq in. One design, with an end mounted reducer, is available in 62 ratios from 7.88 to 1 to 25,573.65 to 1. A second design, with a side mounted reducer, provides a choice of 27 ratios from 27.93 to 1 to 2,511.84 to 1. Standard dc motor has 13 armatures available for up to 50 vdc; it is rated at 2.5 mph at 8,000-17,000 rpm.–Globe Industrial, Inc., Dayton Ohio.

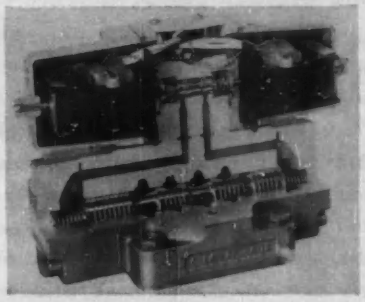
Circle No. 350 on reply card



SLOW SPEED DRIVE

This new miniaturized slow speed drive is designed for light duty applications such as potentiometers, slip rings, and synchros. Basically a drive motor with a miniature gearless speed reducer, the drive is not a substitute for conventional gearhead motors. But the slow speed drive does have the advantages of slow operation, high shock capacity under vibration, and small size. Unit is available with Size 10, 11, or 12 motors, and speed ratios are available in the range of 25 to 1 up to 5,000 to 1. Price: $150-200.–The Barden Corp., Danbury, Conn.

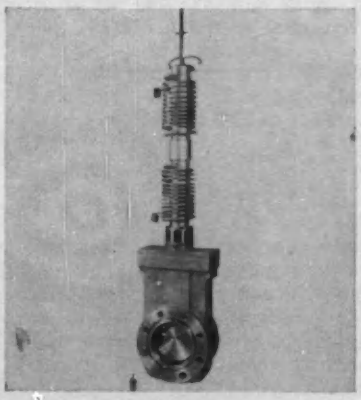
Circle No. 351 on reply card



PIGGYBACK VALVES

Greatly reduced piping is a feature of this new series of piggyback four-way directional control valves. Valves are designed for a wide variety of applications and pressures up to 3,000 psi. Piping is decreased by including an internal drain, thus eliminating the external drain line and the need for a fifth port. Valves are available in ⅛, ⅜, and ¾-in. sizes with the two larger units being available with ½ and 1-in. subplates, respectively.–Racine Hydraulics & Machinery, Inc., Racine, Wis.

Circle No. 352 on reply card



ACTUATED BY HEAT

Based on the design concepts of an automobile engine thermostat that has been available for some time, this new electrothermal actuator is suitable for a long list of applications that

ENGINEERING REPORT ON OTHER BENDIX COMPONENT PACKAGES



NEW 2-SPEED "PANCAKE" SYNCHRO TRANSMITTER



Resists stresses and temperature extremes

This compact, two-speed "pancake" synchro transmitter consistently exhibits an accuracy within thirty seconds of arc under dimensional stresses and wide temperature variations. The same order of accuracy is maintained when the transmitter is used back-to-back with a conventional two-speed control transformer. The synchros are operable from −55°C. to +200°C. They are logical replacements for existing mechanical two-speed transmitters. Their bantam weight (5 oz.) and small size (2.685" O.D. x 1.002" I.D. x 0.562" thick) suits them ideally to vertical gyro gimbals and other assemblies where size and weight are critical factors. Write for complete information.

Manufacturers of

GYROS • ROTATING COMPONENTS RADAR DEVICES • INSTRUMENTATION PACKAGED COMPONENTS

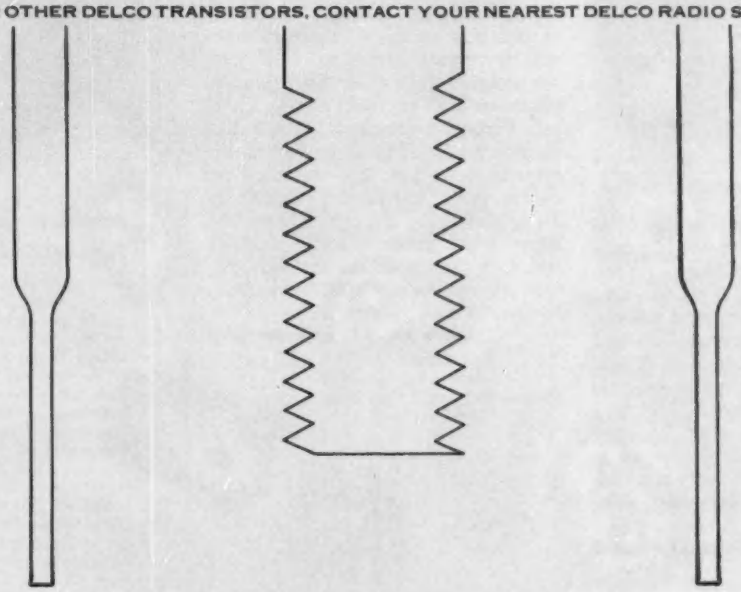
Eclipse-Pioneer Division

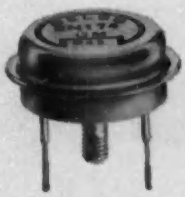
Bendix CORPORATION

Teterboro, N. J.

TAKE A SECOND LOOK

IT'S THE 2N174—PART OF DELCO RADIO'S POWER TRANSISTOR FAMILY WHICH HAS PROVED ITS STUFF FOR YEARS IN HUNDREDS OF MILITARY AND INDUSTRIAL APPLICATIONS: MISSILES, COMMUNICATIONS, DATA PROCESSING, AND ULTRASONICS, TO NAME A FEW. THIS MULTI-PURPOSE PNP GERMANIUM POWER TRANSISTOR HAS THE HIGH PERFORMANCE AND VERSATILITY TO MEET OR EXCEED THE MOST RIGID ELECTRICAL AND ENVIRONMENTAL REQUIREMENTS. ¶ DESIGNED FOR GENERAL USE WITH 28-VOLT POWER SUPPLIES, THE 2N174 MAY ALSO BE USED WITH 12 VOLTS WHERE HIGHER RELIABILITY IS DESIRED. MAXIMUM EMITTER CURRENT—15 AMPERES, MAXIMUM COLLECTOR DIODE RATING—80 VOLTS, THERMAL RESISTANCE—BELOW .6°C/W AND MAXIMUM POWER DISSIPATION—50 WATTS AT 71°C, MOUNTING BASE TEMPERATURE. THE 2N174'S LOW SATURATION RESISTANCE PROVIDES HIGH EFFICIENCY IN SWITCHING OPERATIONS. ¶ LIKE ALL DELCO TRANSISTORS, EVERY 2N174 MUST PASS AT LEAST A DOZEN ELECTRICAL AND ENVIRONMENTAL TESTS—BEFORE AND AFTER AGING—BEFORE IT LEAVES DELCO RADIO'S LABORATORIES. THIS 200 PERCENT TESTING, COMBINED WITH FIVE YEARS OF REFINEMENTS IN MASS PRODUCTION, MEANS CONSISTENT UNIFORMITY IN THE PRODUCT . . . AT A LOW PRICE. ¶ THE 2N174 IS JUST ONE OF MANY DEPENDABLE TRANSISTORS PRODUCED BY DELCO RADIO TO SUPPLY ALL YOUR TRANSISTOR NEEDS. FOR MORE DETAILS OR APPLICATIONS ASSISTANCE ON THE 2N174 OR OTHER DELCO TRANSISTORS, CONTACT YOUR NEAREST DELCO RADIO SALES OFFICE.





Union, New Jersey
324 Chestnut Street
MUrdock 7-3770

Santa Monica, California
726 Santa Monica Blvd.
UPton 0-8807

Chicago, Illinois
5750 West 51st Street
POrtsmouth 7-3500

Detroit, Michigan
57 Harper Avenue
TRinity 3-6560

DELCO RADIO
DEPENDABILITY
RELIABILITY

DIVISION OF GENERAL MOTORS • KOKOMO, INDIANA



DELCO SEMICONDUCTORS NOW AVAILABLE AT THESE DISTRIBUTORS:

New York:
HARVEY RADIO CO., INC.
103 West 43rd St., New York 36, N. Y.
JU 2-1500

San Francisco:
SCHAD ELECTRONIC SUPPLY, INC.
499 South Market St., San Jose 13, Calif.
CY 8-0511

Detroit:
GLENDALE ELECTRONIC SUPPLY COMPANY
12530 Hamilton Ave., Detroit 3, Michigan
TU 3-1500

Boston:
GREENE-SHAW DISTRIBUTING CO.
341 Watertown St., Newton 58, Mass.
WO 9-8900

Philadelphia:
ALMO RADIO COMPANY
913 Arch St., Philadelphia, Pennsylvania
WA 2-5918

Baltimore:
RADIO ELECTRIC SERVICE
5 North Howard St., Baltimore, Maryland
LE 9-3835

Seattle:
C&G ELECTRONICS COMPANY
2221 Third Avenue, Seattle 1, Washington
MA 4-4354

Chicago:
MERQUIP ELECTRONICS, INC.
5904 West Roosevelt, Chicago, Illinois
AU 7-6274

Los Angeles:
RADIO PRODUCTS SALES, INC.
1501 South Hill St., Los Angeles 15, Calif.
RI 8-1271

Minneapolis:
GEORGE SPENCER, INC.
5305 Cedar Lake Rd., Minneapolis 16, Minn.
LI 5-8811

Birmingham:
FORBES DISTRIBUTING CO., INC.
2610 Third Ave. S., Birmingham 5, Ala.
AL 1-4104

West Palm Beach:
GODDARD, INC.
1309-11 N. Dixie, West Palm Beach, Florida
TE 3-5701 or WX-9000

Phoenix:
ASTRONICS, INC.
9310 North Central, Phoenix 20, Arizona
944-1551

Richmond:
MERIDIAN ELECTRONICS, INC.
1001 W. Broad St., Richmond 20, Virginia
EL 5-2834

Cincinnati:
UNITED RADIO, INC.
1314 Vine Street, Cincinnati 10, Ohio
CH 1-6530

Ask for a complete catalog

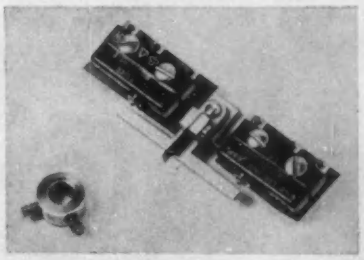
DELCO RADIO
DEPENDABILITY
RELIABILITY

NEW PRODUCTS

do not require instantaneous response. An electric heater immersed in a fluid or wax within the body of the actuator causes a pressure buildup in the fluid or wax due to thermal expansion. This pressure moves a piston resulting in the actuator movement. Units are available to produce forces from 30 to 200 lb and mechanical motion from $\frac{1}{8}$ to 6 in. or more. Large unit is shown mounted on a valve in the photo.—Standard-Thomson Corp., Waltham, Mass.

Circle No. 353 on reply card

COMPONENT PARTS



LIMIT STOP

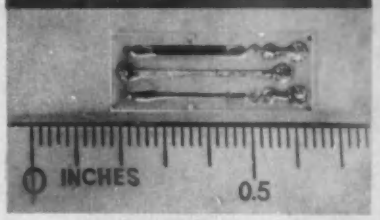
One of a series of special parts and assemblies making up a servo construction system, this 321A adjustable electrical limit stop has operating torque of 0.5 oz-in. Capacity of the miniature switches is 5 amp, 250 vac. Limit is adjustable from 20 to 370 deg with a differential angle of −4 deg. Unit price is $24.50.—Gap Instrument Corp., Newtown, Conn.

Circle No. 354 on reply card

SCR CONTROL

The Model MRC 6203 permits positive firing of all standard models of silicon controlled rectifiers throughout an operating range of 0-85 deg C. The device emits a relatively high, narrow, 3-millisec wide output pulse with an open circuit voltage of 9 volts and a short circuit current of 1 amp. The completely isolated unit is full wave with no common connections between the SCR load and the control windings. It will fire SCR's back to back, in a bridge, or full wave center tap connection. Operating

NEW
MICRO SENSOR™
SEMICONDUCTOR
STRAIN GAGE



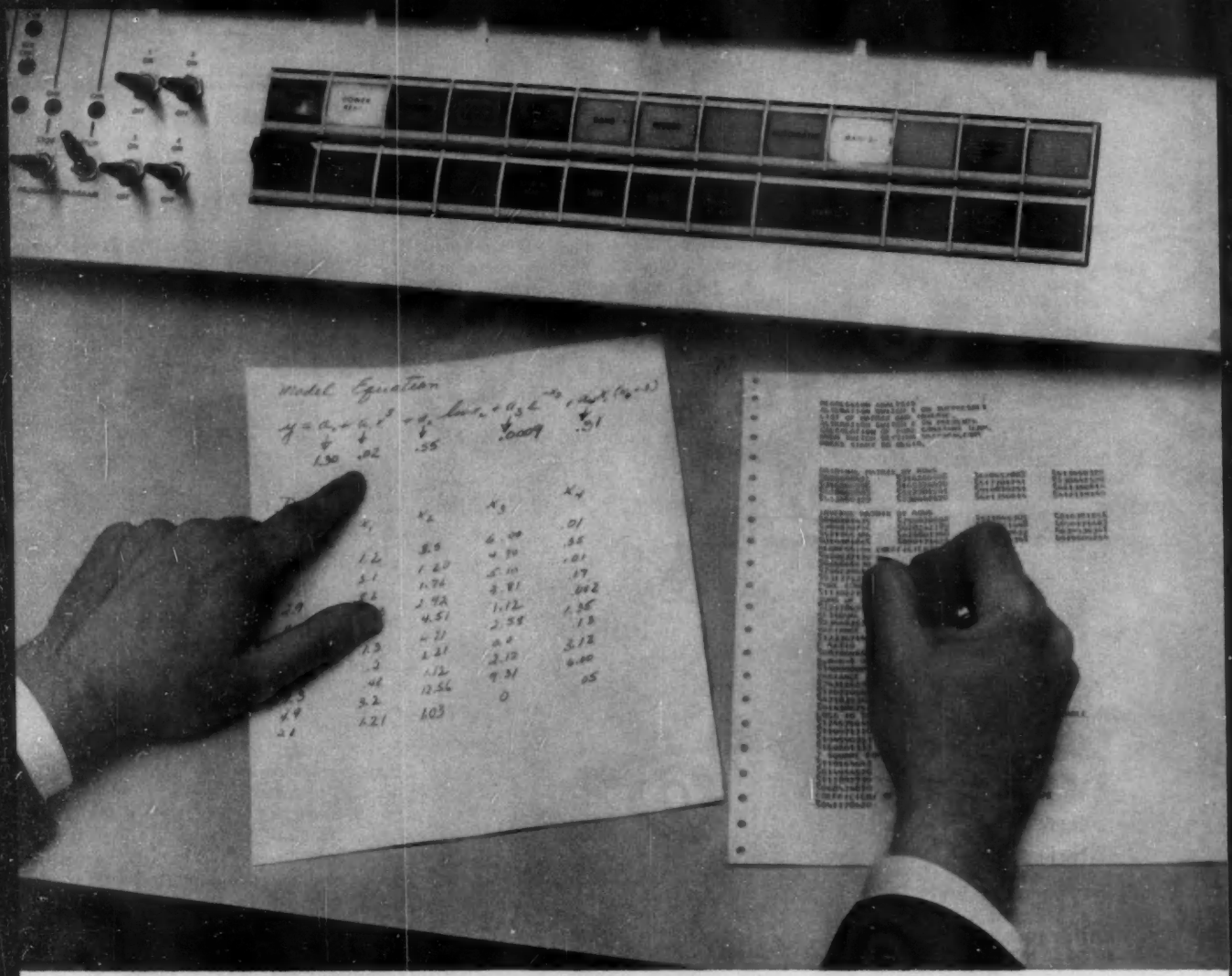
ELIMINATES TEMPERATURE INDUCED STRAIN

MICRO SYSTEMS' self-temperature-compensated semiconductor strain gage provides unusually high output. Temperature effects are reduced to less than 1 micro strain/°F when used on aluminum. For use in experimental stress analysis, military, space, industrial and transducer applications. Low impedance, coupled with high output, results in superior signal to noise ratio. Single crystal structure eliminates hysteresis, provides optimum flexibility.

FEATURES:
- Positive and Negative Gage Factor elements in half bridge configuration.
- Negligible Transverse Sensitivity.
- Apparent Strain $\leqq 1\mu\varepsilon/°F$ on aluminum.
- Temperature Compensated from −65°F to +160°F.
- Strain Range to $3000\mu\varepsilon$.

ALSO AVAILABLE...





Want to find the coefficients? It's easy with the new Regression Analysis program for the IBM 1620

Here's another program offered free-of-charge to users of the IBM 1620 Data Processing System. It gives you the kind of results you might expect only from a much more expensive computer. But users of the 1620 know that its low rental cost is deceptive. The 1620 packs *more computing power per cubic inch* than any other computer in its size range.

The Regression Analysis program is a good example. Suppose you want a fit for production purposes. If you employ more than two variables you probably have difficulty visualizing the representation of your data. If linearity is not the case, you must often guess blindly at a polynomial of high degree, accept or reject the fit with something approaching a sixth sense, and either try again or settle for the results you have.

The new Regression Analysis program lets you handle expressions containing up to *24 variables*. If you have the even more complicated task of handling many dependent variables, the program will generate regression coefficients with a maximum number of dependent variables not exceeding one-half the number of independent variables.

This program will also fit non-linear functions and hyper-surfaces. Compare this performance with that of any other computer in the 1620's price range.

A basic 1620 installation rents for just $1600 per month. For details, contact your local IBM Representative.



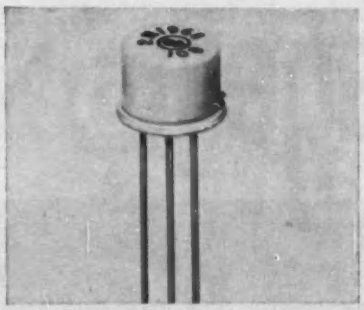
IBM's 1620 is a compact desk-size computer.

IBM®
DATA PROCESSING

CIRCLE 212 ON READER SERVICE CARD

voltage is 120 vac. The unit measures 4⅞ x 3⅞ x 3⅜ in. Price: $95.–Fairfield Controls, Inc., Stamford, Conn.

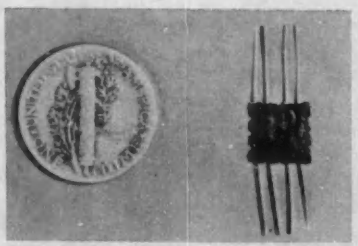
Circle No. 355 on reply card



TWO-POSITION SWITCH

Announced as the first alloyed junction, four-layer semiconductor device, the Dynaquad is a two-position switch with capacities and speeds like those of a computer. The three-terminal PNPN germanium device switches in the megacycle range with rise times on the order of 0.1 microsec. Output voltage swing can be 35 volts. A single Dynaquad can replace a number of transistors and other components in some applications and, in simple on-off switching, it behaves as a pulse operated latching relay without bounce, chatter, or sticking contacts. Types 2N1966, 2N1967, and 2N1968 are available in sample quantities at prices from $3.10.–Tung-Sol Electric, Inc., Newark, N. J.

Circle No. 356 on reply card



MICROMINIATURE FLIP-FLOP

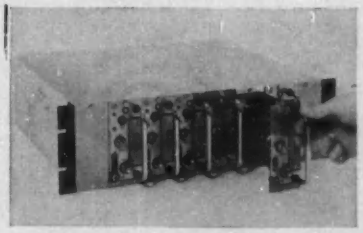
Produced using an approach to microminiaturization termed nanocircuitry by its developers, this 12-component flip-flop is just 0.310 in. square. The 12 components (six resistors, two capacitors, two transistors, and two diodes) are passivated by a silicon oxide film and mounted on a ceramic substrate. Failure rate is as low as 0.001 percent per thousand hours. Circuits are available initially on a custom basis and cost is expected to be the same as that of standard components for assembly.–General Instrument Semiconductor Div., Newark, N. J.

Circle No. 357 on reply card

LOW COST SCR GATE

Said to be smaller and less expensive than previously available gating devices for silicon controlled rectifiers, the Siligate functions with a single SCR in half-wave, two SCR's in full wave, and two SCR's back-to-back for ac. The device may be controlled by dc current, by variable resistance, or directly by transistors. Output is limited in voltage to a safe value for SCR's of 3-amp capacity or larger, yet is capable of ample drive for 100-amp SCR's. Power consumption is 1.25 watts. The Siligate is sealed in a case measuring 2⅛ x 2½ x 3½ in. Prices are $85 or $110, depending on voltage and frequency.–Dresser Electronics, HST Div., Garland, Tex.

Circle No. 358 on reply card



TRANSDUCER CONDITIONERS

A new and different package design is the highlight of two new transducer signal conditioning units now available. Both the PS-290 power supply and the PB-290 power and balance unit use plug-in circuit cards to mount as many as eight channels in a 5¼ in. high panel of a standard relay rack. Entry from the front is possible for bridge completion, balancing, and access to calibration resistors. The PS-290 provides close regulation and complete isolation from the line for outputs ranging from millivolts to 16 volts. The PB-290 includes, in addition to power cards, conditioning cards for balance, calibration, and monitoring functions. A thumbwheel switch selects calibration resistor and displays its value.–Microdot, Inc., S. Pasadena, Calif.

Circle No. 359 on reply card

FAST MODULAR MEMORY

Said to be available commercially for the first time, this high speed modu-

NEW

⅛" DIA. SEMICONDUCTOR PRESSURE TRANSDUCER



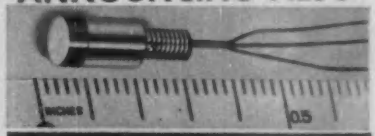
FOR HIGH RESPONSE APPLICATIONS

Solid state elements of MICRO SYSTEMS' new subminiature pressure transducer convert pressure induced strains to a high level output signal. Type PO3BA5 transducer needs no pre-amp; can directly drive recorders, oscilloscopes, etc. Its broad military and commercial *applications* include wind tunnel and engineering model work, rocket engine testing, telemetering and process control.

FEATURES:

- Extremely high natural frequency... 40 KC for 100 psia range.
- 1 volt, full scale open circuit output.
- Micro Sensor® semiconductor elements.
- Ranges from 0-50 psia to 0-500 psia.

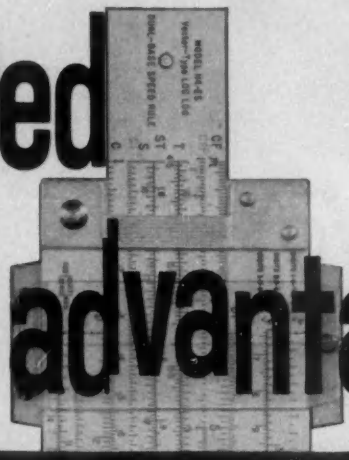
ANNOUNCING ALSO



DIAMETER PRESSURE TRANSDUCER, Type PO3CA7, designed for exactly for model work. Has high natural frequency and pressure overload safety factor. Units available with ranges from 5 to 100 psia. Write for illustrated literature containing complete specifications, price and delivery information.

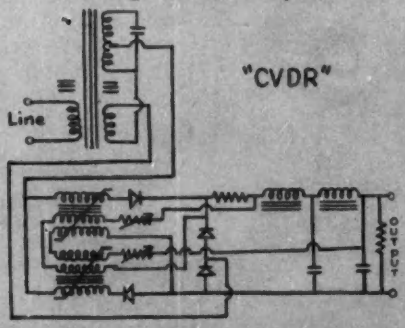
MSI

calculated advantage



New SOLA "CVDR" d-c supply simplifies missile-age circuit design, reduces costs.

It's a natural for computers, communications equipment, and similarly sophisticated electronic gear. Made for today's stringent operating parameters. Ends costly dependence on over-engineered d-c power sources.



CVDR provides both line and load regulation without tubes or transistors. Line regulation ±1%, for ±15% line voltage changes; 1% load regulation from zero to full load; 1% peak to peak ripple. Fits 19" relay racks, and measures only 3½" high. Custom configurations and power ratings available on special order.

Line voltage stabilization is by means of the Sola "CV" self-regulating transformer. Load voltage stabilization is accomplished by the series "IX" voltage drop in the saturable reactor (see schematic). This voltage drop is controlled by the load current itself.

CVDR is ready right now, off-the-shelf, in units rated 6-volts, 10-amps . . . and 12, 18 or 24 volts, 5-amps. For outstanding reliability in a-c and d-c power supplies tailored to every application, see your SOLA representative . . . or write to address below.

SOLA ELECTRIC CO., 1717 Busse Road, Elk Grove Village, Ill., HEmpstead 9-2800
IN CANADA, Sola-Basic Products Ltd., 377 Evans Ave., Toronto 18, Ontario

SOLA

BPC

Division of Basic Products Corporation

5-29-61

For all your a-c and d-c power supply requirements or special engineering, contact your nearest SOLA representative:

CALIFORNIA, San Francisco; Sola Electric Co., Three W. 37 Ave., San Mateo, FIreside 1-6538 • Los Angeles; Sola Electric Co., 2907 West Vernon Avenue, AXminster 2-0166

COLORADO, Denver; Slaybaugh & Thompson 100 W. 13th Avenue; AComa 2-5826

FLORIDA, Winter Park; James Millar Assoc., P. O. Box 1603; Midway 7-7407

GEORGIA, Atlanta; James Millar Assoc., 1036 Peachtree Street N. E., TRinity 6-0919

INDIANA, Indianapolis; R. O. Whitesell & Assoc., 6620 E. Washington Street; FLeetwood 9-5374

IOWA, Des Moines; McDowell-Redlingshafer Sales Co., 3615 Olive St.; JEfferson 3-3277

KENTUCKY, Louisville; R. O. Whitesell & Assoc., 400 N. 38 Street; SPring 6-2024

MASSACHUSETTS, Newton; Sola Electric Co., 272 Centre Street; Bigelow 4-3354

MICHIGAN, Detroit; R. C. Merchant & Co., Inc., 18411 W. McNichols Rd.; KEnwood 5-6000

MINNESOTA, Minneapolis; Heimann Co., 1711 Hawthorne Avenue; FEderal 2-5457

MISSOURI, Kansas City; McDowell-Redlingshafer Sales Co., 1103 E. Armour; WEstport 1-5622 • St. Louis; McDowell-Redlingshafer Sales Co., 3615 Olive Street; JEfferson 3-3277

NEW JERSEY, Little Ferry; Sola Electric Co., 84 Industrial Avenue; HUbbard 9-1060

NEW YORK, Buffalo; R. W. Mitscher Co., 487 Ellicot Square Building; TL 4-2517

NORTH CAROLINA, Charlotte; Ranson, Wallace & Co., 116½ E. 4th St.; EDison 4-4244

OHIO, Cleveland; Sola Electric Co., 14235 Detroit Avenue; LAkewood 1-8038

PENNSYLVANIA, Philadelphia; Sola Electric Co., (Philadelphia answering service — WAlnut 2-5340); or 210 North 6 Street, Camden 2, N. J.; EMerson 5-7744 • Pittsburgh; R. G. Sidnell & Co., 675 Princeton Blvd.; CHurchill 2-1476

TEXAS, Dallas; Robert E. Nesbitt Co., 1925 Cedar Springs; Riverside 7-4145

WASHINGTON, Seattle; Northwestern Agencies, Inc., 4130 First Ave. So.; MAine 3-8882

WASHINGTON, D. C.; Sola Electric Co., contact 8719 Colesville Rd., Silver Spring, Md.; JUniper 5-0331

NEW PRODUCTS

lar memory has a full read-write cycle time of 1 microsec with access time of 0.4 microsec. The modular units each have a capacity of up to 1,024 words, 50 bits in length. Capacity is expandable in modules of 1,024 addresses and word lengths up to 200 bits. Components are stacked rather than mounted on cards for improved packing density. Power supply regulation is needed to no better than ±5 percent. Low power dissipation is possible with full read driving current of only 360 ma.—Daystrom, Inc., Military Electronics Div., Archbald, Pa.

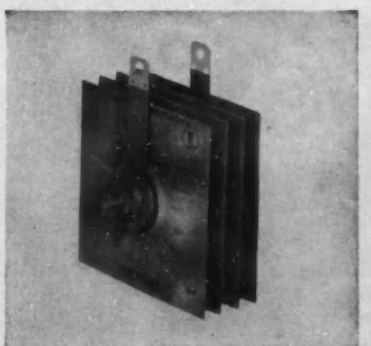
Circle No. 360 on reply card

PLUS . . .

(361) Newest addition to the R Series of **ferrite memories** from **Ampex Computer Products Co.,** Culver City, Calif., is the RQA with a 5-microsec memory cycle, 2-microsec access time, and 2.5-microsec buffer cycle. . . . (362) Two new models (710 and 711) of stable **millivolt discriminators** for use in automatic testing, process control, and nuclear reactor monitoring are now available from **Keithley Instruments, Inc.,** Cleveland, Ohio.

Circle 361 or 362 on reply card

ACCESSORIES & MATERIALS

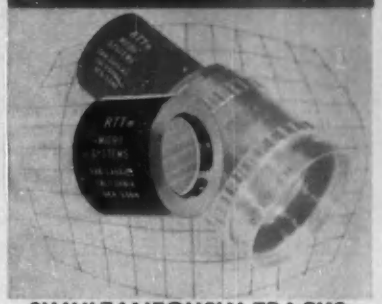


OVERVOLTAGE PROTECTOR

The Voltrap surge suppressor provides overvoltage protection for silicon and germanium cells, controlled rectifiers, and similar devices. Its zener-type volt-ampere characteristic allows a shunt path for transient overvoltages and maintains a limit past

NEW

RADIATION TRACKING TRANSDUCER



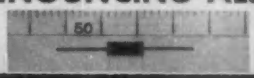
SIMULTANEOUSLY TRACKS LIGHT IN TWO AXES

MICRO SYSTEMS' new single-cell photovoltaic transducer, Model XY20, detects position of visible to near infrared radiation. Four types available for "off-the-shelf" delivery with spectral response from 0.5 to 1.1 microns and peak response of 0.80 micron.

FEATURES:

- Tracks radiation in two axes simultaneously.
- Proportional output over wide angles.
- High resolution, accuracy and reliability.
- Field sizes of 0.5" and 0.2".
- Internal impedance of 4000 ohms.
- 5 microseconds response time.
- Light intensity readout, independent of position.

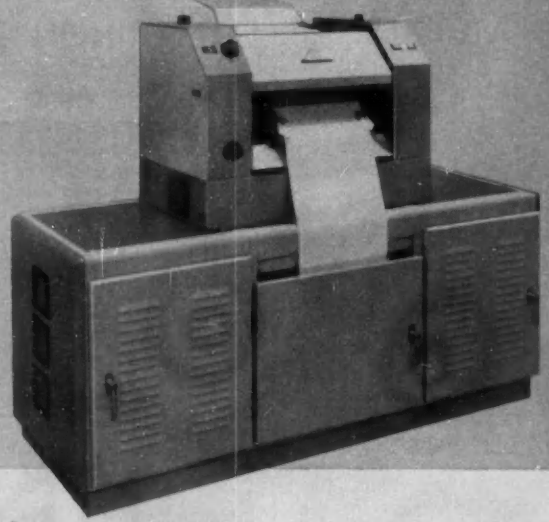
ANNOUNCING ALSO





ANELEX

Wherever a data processing system is judged by the quality and volume of document production, no other equipment has been able to equal the speed and consistent quality or the reliability of Anelex High Speed Line Printing Systems.



Further information available upon request

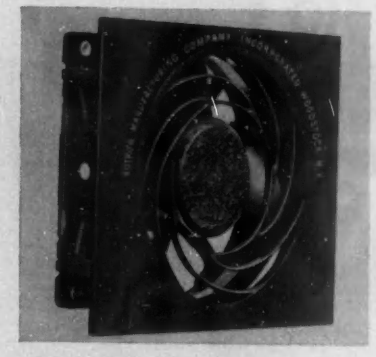
ANELEX CORPORATION

154 Causeway Street, Boston 14, Massachusetts

NEW PRODUCTS

which surge voltage cannot rise. Polarized and nonpolarized units, multiple assemblies of polarized and nonpolarized units, and special models are available with ratings of 2-85 amp max discharge current and 30-480 vac rms. Power drawn is small. —Westinghouse Electric Corp., Pittsburgh, Pa.

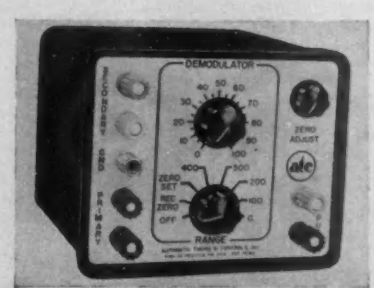
Circle No. 363 on reply card



COOLING FAN

Featuring several improvements over the previous model, this Gold Seal Muffin fan is available in four versions: skeleton fan, fan and motor on spider frame; venturi fan, mounted in molded block; grille fan, with snap-in grille (shown above); and filter fan, with mesh filter along with grille. Unit measures just 4⅛ in. square by 1¼ in. deep. New model offers less vibration and longer bearing life, better impact resistance, reduced chance of in-use shorts, and better airflow. Fan is capable of moving up to 100 cfm without grille or filter installed. Complete grilled, filtered units are about $8 in quantity.—Rotron Manufacturing Co., Inc., Woodstock, N. Y.

Circle No. 364 on reply card



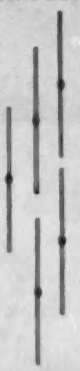
CONVERTS LVDT OUTPUT

The Atcotran 6101 E transistorized demodulator is designed to convert

2

NEW PRODUCT ADVANCES FROM Transitron

ACTUAL SIZE



TMD-914 and TMD-916 DIFFUSED SILICON MICRODIODES MICRO-EQUIVALENTS of the 1N914 and 1N916

Duplicating the specifications of the popular 1N914 and 1N916, these microminiature very fast switching silicon diodes offer low capacitance and are designed for use in extremely high speed transistorized computer circuitry. Their durable construction in an all-glass package features TRUE hermetic sealing and a unit capable of providing long-term reliability under extreme environmental conditions.

Recovery time: 0.004 micro-second.

SPECIFICATIONS AT 25°C

	TMD-914	TMD-916
Maximum Forward Voltage at 10mA	1 Volt	1 Volt
Maximum Inverse Current at 20V	.025 μA	.025μA
Minimum Inverse Voltage at 100μA	100 Volts	100 Volts
Maximum Capacitance at 0 Volts	4 μμF	2 μμF

For further information, write for Bulletin PB-71C. **CIRCLE 217 ON READER SERVICE CARD**

6.3 VOLT CERTIFIED SILICON VOLTAGE REFERENCES



ACTUAL SIZE

Now, for the first time in the industry, silicon voltage references that have exhibited voltage stabilities as low as ±.002% for 1000 hours are being CERTIFIED and offered by Transitron. These significant features are associated with each unit:

- Actual readings recorded periodically over 1000 hours included with each certification document.
- Serialization of units for convenient reference to their production and life test histories at Transitron.

Manufacturers of missiles and precision instruments who require a stable voltage reference of small size and weight may look to Transitron for these references which are certified at point of purchase.

Type	Certified* Voltage Stability (%)	Voltage Range at I_Z = 7.5mA at 25°C (Volts) Min.	Max.	Temperature Stability Maximum Voltage Change (+25°C to +100°C) at I_Z = 7.5mA (Volts)	Maximum Dynamic Resistance at I_Z = 7.5mA at 25°C (Ohms)
1N3501	±0.01	6.2	6.5	±0.006	12
1N3502	±0.01	6.2	6.5	±0.003	12
1N3503	±0.005	6.2	6.5	±0.006	12
1N3504	±0.002	6.2	6.5	±0.006	12

*Voltage References certified for voltage stability observed during 1000 hours operation.

For further information, write for Bulletin TE-1352F-1.

CIRCLE 308 ON READER SERVICE CARD

Transitron

electronic corporation

wakefield, melrose, boston, mass.

SALES OFFICES IN PRINCIPAL CITIES THROUGHOUT THE U.S.A. AND EUROPE • CABLE ADDRESS: TRELCO

For quantities 1-999 call your nearest Transitron Industrial Distributor.

Gertsch announces:

the CRB line of complex ratio bridges

Ideal for voltage and phase comparison.

Measures complex voltage ratios — both in-phase and quadrature — with high accuracy.

These Gertsch CRB instruments are designed for testing 3- or 4-terminal networks, including transformers, synchros, resolvers, gyros, and transducers. The Gertsch line includes:

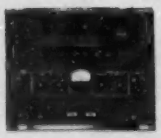


SOLID STATE BRIDGE—Model CRB-4. Instrument is fully transistorized . . . highly accurate. A self-contained, phase-sensitive null indicator permits rapid measurements. $R_x + R_y$ voltage ratios are read from concentric switch dials. *Battery or line* operation . . . case or rack mounting. Operating frequency range: 380-420 cps. Weight 20 pounds.



COMPLEX RATIO BRIDGE—Models CRB-1B and CRB-2B. In these units, quadrature component reading is indicated either as rectangular coordinate, tan θ, or θ directly in degrees. Useful for measuring angles as small as .001°. Six-place resolution, with high accuracy. Cabinet or rack mounting.

CRB-1B	30-1,000 cps	2.5 f or 200 V max.
CRB-2B	50-3,000 cps	.35 f or 200 V max.



AUTOMATIC COMPLEX RATIO BRIDGE—Model CRB-3. A self-nulling AC bridge with digital readout of both in-phase and quadrature voltage ratios. Excellent for production testing.

Accuracy of bridge is .002% max. Five-place resolution, with automatic quadrant indication. Unit is self-contained, requiring no external calibration sources, and is equipped for external printer readout.

Complete literature on all units sent on request. Bulletin CRB.

Gertsch

GERTSCH PRODUCTS, INC.

3211 S. La Cienega Blvd., Los Angeles 16, Calif. • UPton 0-2761 • VErmont 9-2201

the ac millivolt output of a linear variable differential transformer into dc for operating potentiometric or galvanometric recorders and indicators. Unique oscillator and demodulator circuits provide stable conversion in addition to flexible adjustment of zero and range. Output is phase sensitive and can be either 1-0-1 or 0-1 ma dc into a 1,500 ohm load. Voltage outputs to 1.5 vdc are produced. —Automatic Timing & Controls, Inc., King of Prussia, Pa.

Circle No. 365 on reply card

SYSTEMS

CORE AND DRUM STORAGE

Said to be the first computer in the medium size field to offer both magnetic core and drum memory, the Solid-State II system is termed the fastest and most powerful computer in its class. Access time to the core memory is 1.5 microsec. Data can be moved between the drum and the core in the same access time per digit with up to 2,200 digits in a single operation and with a new variable multiword transfer feature. Nominal capacity of the core memory is 14,080 digits; of the drum memory, 28,600 to 96,800.—Univac, Div. of Sperry Rand Corp., New York, N. Y.

Circle No. 366 on reply card

LARGE SCALE COMPUTER

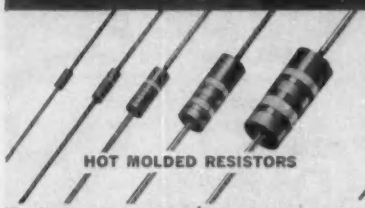
Called by its developer one of the fastest and most powerful computer systems in the world, the L-3060 is a transistorized digital system specifically designed for converting large volumes of raw data into accessible information. High speed core memory of 144,000 words, a random access magnetic disc memory of 3.25 million words, and magnetic tape files of 9 million words are used. A typical multiple computer system will perform 2.48 million operations per sec. Basic add time is 2 microsec, and average access time is 0.75 microsec. System can read 800 cards per min and punch 250 cards per min. Delivery schedule is 18 months.—Librascope Div., General Precision, Inc., Glendale, Calif.

Circle No. 367 on reply card

ALLEN-BRADLEY

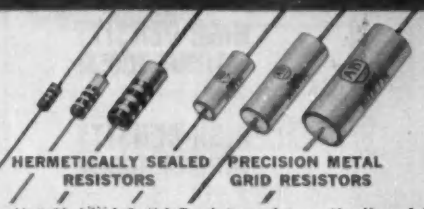
Electronic Components

...The universal standard for reliability and superior performance



HOT MOLDED RESISTORS

Exclusive Hot Molded Resistors are the "quality" standard of industry all over the world. Conservatively rated. Stable and uniform characteristics assure superior performance. No known instance of catastrophic failure. Rated 1/10, 1/4, 1/2, 1, and 2 watts at 70°C. Res. to 22 meg. Tol: 5, 10, and 20%.

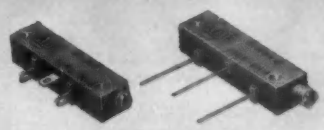


HERMETICALLY SEALED RESISTORS

PRECISION METAL GRID RESISTORS

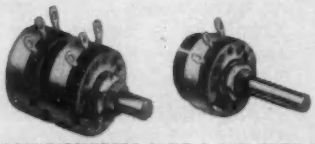
Hot Molded Solid Resistors, hermetically sealed in ceramic tubes, remain stable. Rated 1/8, 1/3, and 1 watt. Res. to 22 meg.

Precision Resistors—Metal Grid Construction—hermetically sealed. Noninductive. Tol: 0.1, 0.25, 0.5, & 1.0%. TC ±25 PPM/°C. Rated 1/4, 1/2, and 1 watt at 125°C.



ADJUSTABLE FIXED RESISTORS

Adjustable Fixed Resistors. Resistance element and terminals hot molded into integral unit with insulated mounting base. Stepless adjustment. Noninductive. Remains fixed in "set" position. Watertight. Rated 1/4 watt at 70°C. Values to 2.5 meg. Tol: 10% and 20%.



POTENTIOMETERS TYPE J AND TYPE K

Type J Potentiometers. Solid, hot molded resistance element. Smooth, quiet control which improves with long life. Compact. Rated 2.25 watts at 70°C. Values to 5 meg.

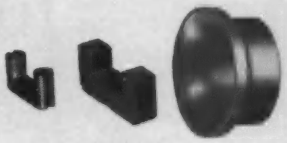
Type K Potentiometers. Same as the above but rated 1 watt at 125°C; 2 watts at 100°C; and 3 watts at 70°C.



POTENTIOMETERS TYPE G AND TYPE L

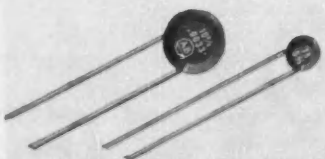
Type G Potentiometers are miniature controls with solid molded resistance element. Only 1/2" diam. Smooth control—also improves with age. Rated 1/2 watt at 70°C. Values to 5 meg.

Type L Potentiometers are similar to Type G but rated 1/2 watt at 100°C. Can be used up to 150°C with reduced "load."



FERRITES

Ferrites in a wide range of "items," such as flared rings, quarter rounds, U cores, E cores, cup cores, toroids, etc., can be supplied for a very large variety of applications. Uniform magnetic characteristics. Ceramic permanent magnets having a high energy-to-weight ratio also available.



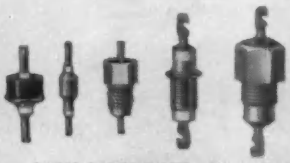
HIGH TEMPERATURE CAPACITORS

High Temperature Capacitors. Ceramic disc type—encapsulated in a ceramic case—for use in high quality apparatus where reliability and superior performance are important. For continuous operation at 500 v in 150°C ambient. Values from 2.2 to 3300 mmf. Tol: 5%, 10%, and 20%.



FEED-THRU AND STAND-OFF CAPACITORS

Feed-thru and Stand-off Capacitors for use at VHF and UHF frequencies. Discoidal design eliminates all parallel resonance effects at 1000 Mcps and less. Standard values 470 mmf ±20% and 1000 mmf —0 +100%. Special values from 6.8 mmf to 1500 mmf. Rated to 500 v DC max.



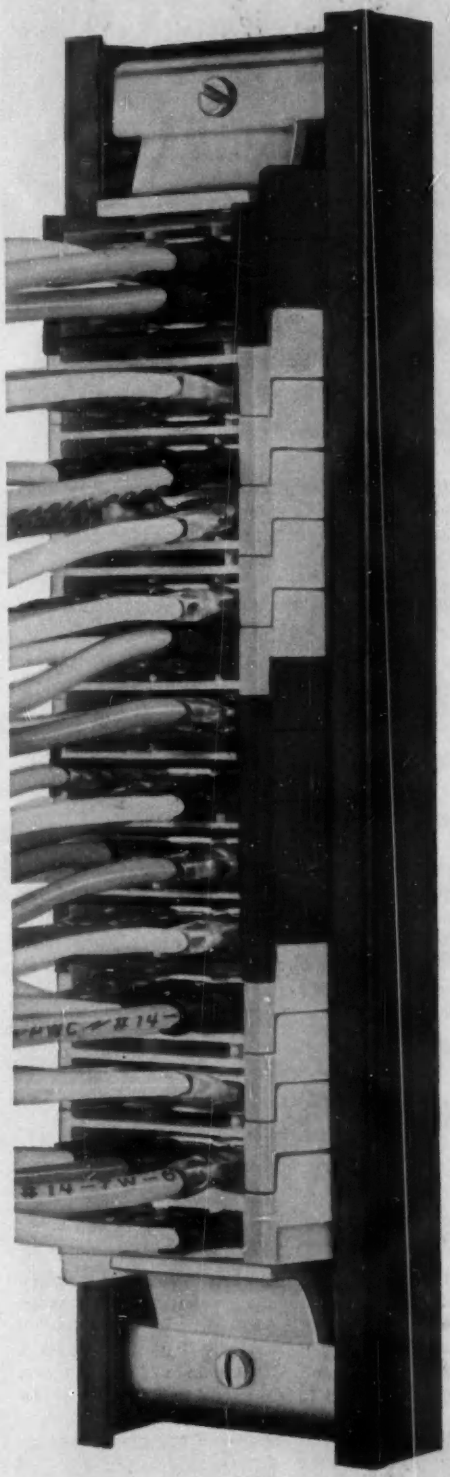
HIGH FREQUENCY LOW-PASS FILTERS

High Frequency Low-Pass Filters for eliminating undesired radiation in the range from 100 to 8000 Mcps. Effective filtering actually increases with frequency over a wide band. Attenuation to 75 db and more. Ratings to 500 v, and to 5 amp DC or low frequency AC current.

ALLEN-BRADLEY

Allen-Bradley Co., 210 W. Greenfield Ave., Milwaukee 4, Wisconsin
In Canada: Allen-Bradley Canada Ltd., Galt, Ont.

QUALITY ELECTRONIC COMPONENTS



HIGH-DENSITY
WITHOUT TOOLS!

HIGH-DENSITY
WITHOUT TOOLS!

HIGH-DENSITY
WITHOUT TOOLS!

HIGH-DENSITY
WITHOUT TOOLS!

THE ONE-TRACK MIND OF TERMI-BLOK*

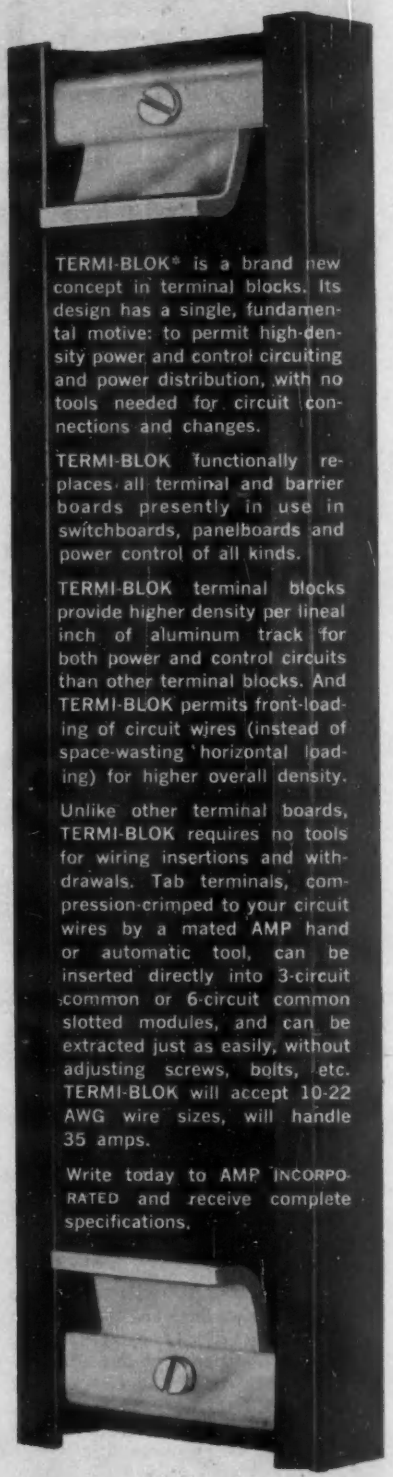
HIGH-DENSITY
WITHOUT TOOLS!

HIGH-DENSITY
WITHOUT TOOLS!

HIGH-DENSITY
WITHOUT TOOLS!

HIGH-DENSITY
WITHOUT TOOLS!

* Trademark



TERMI-BLOK* is a brand new concept in terminal blocks. Its design has a single, fundamental motive: to permit high-density power and control circuiting and power distribution, with no tools needed for circuit connections and changes.

TERMI-BLOK functionally replaces all terminal and barrier boards presently in use in switchboards, panelboards and power control of all kinds.

TERMI-BLOK terminal blocks provide higher density per lineal inch of aluminum track for both power and control circuits than other terminal blocks. And TERMI-BLOK permits front-loading of circuit wires (instead of space-wasting 'horizontal loading) for higher overall density.

Unlike other terminal boards, TERMI-BLOK requires no tools for wiring insertions and withdrawals. Tab terminals, compression-crimped to your circuit wires by a mated AMP hand or automatic tool, can be inserted directly into 3-circuit common or 6-circuit common slotted modules, and can be extracted just as easily, without adjusting screws, bolts, etc. TERMI-BLOK will accept 10-22 AWG wire sizes, will handle 35 amps.

Write today to AMP INCORPORATED and receive complete specifications.

AMP INCORPORATED

GENERAL OFFICES: HARRISBURG, PENNSYLVANIA

AMP products and engineering assistance are available through subsidiary companies in: Australia • Canada • England • France • Holland • Italy • Japan • Mexico • West Germany

COMING NEXT MONTH

- **Computers Comparison Series Starts**

  CtE's Information Systems Section introduces a new series: in all, the most important reference source on computers publicly available. Some 40 digital computers will be compared—unit by unit, feature by feature.

- **Control Terminology**

  Surveys standards activities on control terms by U.S. societies.

- **Comparing Electronics and Pneumatic Instruments**

  Chemical company reports on installation of two comparable control systems.

- **Predicting Performance of Analyzers**

  Defines and discusses error sources in stream analyzers.

- **Counting on a Magnetic Drum**

  For cross totaling and sorting counts, computers may offer economies.

- **Swiveled Rocket Motor**

  Technical study reveals design of rocket motor for short range maneuverability.

- **Designing Temperature Bridges**

  Graph plots response of Wheatstone bridge, based on variable arms change.

Postage Will be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY MAIL

First Class Permit No. 43, (Sec. P. L. & R.) Ridgefield, Conn.

Reader Service Department 2 (9/61)

CONTROL ENGINEERING

P. O. Box 623

Ridgefield, Conn.

TURN PAGE

to Get More Information About

1. Advertised products

2. New product items

3. Catalogs and Bulletins

4. Article reprints

All advertisements, new products, and literature items are numbered for your convenience.

Get YOUR own personal copy each month. Complete and mail this card TODAY!

NEW SUBSCRIPTION APPLICATION CARD

(Subscriptions solicited only from engineers and technical management men)

Yes! I want my own personal copy of CONTROL ENGINEERING every month. Enter my subscription at once for 1 year at $3.* ☐ New ☐ Renewal

Check here ☐ for 3 years at $5 *

(*United States and Canada only. Overseas rates on request.)

☐ Payment enclosed ☐ Bill me ☐ Bill company

ON

U

Name_____ Position_____

Home Address_____

City_____ Zone_____ State_____

Company Name_____

Product Manufactured or Service Performed by Company_____

BUSINESS ADDRESS

Street_____ City_____ State_____ Zone_____

☐ Check here if you want publication sent to business address

Please print — and fill out completely for best service

ON-RS-9/1

ADVERTISEMENTS *Mail Before December 1, 1961*

1	15	29	43	57	71	85	99	113	127	141	155	169	183	197	211	225	239	253	267	281	295
2	16	30	44	58	72	86	100	114	128	142	156	170	184	198	212	226	240	254	268	282	296
3	17	31	45	59	73	87	101	115	129	143	157	171	185	199	213	227	241	255	269	283	297
4	18	32	46	60	74	88	102	116	130	144	158	172	186	200	214	228	242	256	270	284	298
5	19	33	47	61	75	89	103	117	131	145	159	173	187	201	215	229	243	257	271	285	299
6	20	34	48	62	76	90	104	118	132	146	160	174	188	202	216	230	244	258	272	286	300
7	21	35	49	63	77	91	105	119	133	147	161	175	189	203	217	231	245	259	273	287	301
8	22	36	50	64	78	92	106	120	134	148	162	176	190	204	218	232	246	260	274	288	302
9	23	37	51	65	79	93	107	121	135	149	163	177	191	205	219	233	247	261	275	289	303
10	24	38	52	66	80	94	108	122	136	150	164	178	192	206	220	234	248	262	276	290	304
11	25	39	53	67	81	95	109	123	137	151	165	179	193	207	221	235	249	263	277	291	305
12	26	40	54	68	82	96	110	124	138	152	166	180	194	208	222	236	250	264	278	292	306
13	27	41	55	69	83	97	111	125	139	153	167	181	195	209	223	237	251	265	279	293	307
14	28	42	56	70	84	98	112	126	140	154	168	182	196	210	224	238	252	266	280	294	308

NEW PRODUCTS & BULLETINS

309	320	331	342	353	364	375	386	397	408	419	430	441	452	463
310	321	332	343	354	365	376	387	398	409	420	431	442	453	464
311	322	333	344	355	366	377	388	399	410	421	432	443	454	465
312	323	334	345	356	367	378	389	400	411	422	433	444	455	466
313	324	335	346	357	368	379	390	401	412	423	434	445	456	467
314	325	336	347	358	369	380	391	402	413	424	435	446	457	468
315	326	337	348	359	370	381	392	403	414	425	436	447	458	469
316	327	338	349	360	371	382	393	404	415	426	437	448	459	470
317	328	339	350	361	372	383	394	405	416	427	438	449	460	471
318	329	340	351	352	373	384	395	406	417	428	439	450	461	472
319	330	341	352	363	374	385	396	407	418	429	440	451	462	473

REPRINTS

474	485	496	507
475	486	497	508
476	487	498	509
477	488	499	510
478	489	500	511
479	490	501	512
480	491	502	513
481	492	503	514
482	493	504	515
483	494	505	516
484	495	506	517

Name *Title*

Company

Address *City* *Zone* *State*

Index of advertised equipment, new products, and bulletins. For additional information circle number on card corresponding to number to left of item.

1. SYSTEMS

Advertisements

24—Low cost digital control computer, p. 24
29—Iterative analog computers, p. 29
66—Guidance, fire control systems, p. 66
85—Process control systems, p. 84
87—Infrared systems, components, p. 87
96—Computer process control, p. 96
97—Packaged hydraulic systems, p. 97
191—Monitoring and indicating system, p. 191
202—Electromechanical tracer systems, p. 202
212—Desk size computer, p. 212

New Products

366—Computer with core, drum stores, p. 218
367—Large, fast computer, p. 218

Catalogs and Bulletins

401—Heating furnace controls, p. 239
411—Nuclear reactor controls, p. 241

2. DATA HANDLING AND DISPLAY EQUIPMENT

Advertisements

2—Data acquisition, processing gear, p. 2
28—Photocell reader, shaft encoder, p. 28
40—Low cost digital readout, p. 40
43—Spaceborne paper tape reader, p. 43
55—Low to high sensitivity recorders, p. 55
63—High resolution computer monitor, p. 63
68—Production data gathering net, p. 68
73—Direct writing oscillograph, p. 73
79—Electroluminescent readouts, p. 79
80—Card, tape programming units, p. 80
88—Solid state annunciators, p. 88
99—Data accumulation systems, p. 98
101—Direct writing recorder, p. 101
110—Reliable digital printers, p. 110
193—Versatile pot recorder, p. 193
216—High speed line printers, p. 216
237—Oscillograph with new timer, p. 237
243—Flow measuring recorder, p. 243
257—Low price tape setup, p. 257
275—Lightweight tape recorder, 4th cover
290—Small data acquisition set, p. 244
298—Buffer for printers, p. 256

New Products

309—Miniature, plug-in annunciators, p. 189
310—Fiber optic CRT, p. 189
311—Paper or card printer, p. 189
312—Fast character generator, p. 189
313—Pulse code telemeter system, p. 189
314—Information logging set, p. 189
315—High speed tape reader, p. 190
316—Punched tape programmer, p. 190
317—Compact character generator, p. 192

Catalogs and Bulletins

410—Digital instrumentation units, p. 241
417—Transducer disc indicators, p. 243

3. RESEARCH, TEST, AND DEVELOPMENT EQUIPMENT

Advertisements

1—Overranging digital voltmeter, p. 1
5—100-Mcps universal counter-timer, p. 5
50—Two reading per sec DVM, p. 50
58—Transistor curve tracer, p. 58
77—Complete line of DVM's, p. 76
78—Analog to frequency converter, p. 78
107—Transistorized pH analyzer, p. 107
111—Dual electronic multiplier, p. 111
228—Precision mercury manometer, p. 228
235—Ac-dc converter, voltmeter, p. 235
248—Resolver test stand, p. 248
250—Versatile automatic circuit tester, p. 250
260—Temperature sensitive coatings, p. 260
291—Servovalve amplifier, p. 248
299—Phase sensitive null meter, p. 257
300—Accurate temperature chamber, p. 258
306—Binary operated readout, p. 262

New Products

318—Magamp-core tester, p. 192
319—Precise angle positioner, p. 194
320—V-scan shaft encoder tester, p. 194
321—Short-interval counter, p. 196
322—Small-size comparator, p. 196
323—High voltage diode tester, p. 196
324—Low cost digital ohmmeter, p. 198

Catalogs and Bulletins

400—Pumps for high vacuum, p. 239
405—Scientific, testing instruments, p. 239
406—X-ray analysis equipment, p. 241
412—Electrical measuring instruments, p. 243

4. PRIMARY ELEMENTS AND TRANSDUCERS

Advertisements

7—Rugged turbine flowmeter, p. 7
11—Easily adjustable ganged pots, p. 11
13—Accurate level transmitter, p. 12
15—High resolution motion sensor, p. 15
22—Transmitter, flowmeter, changer, p. 22
38—Accurate metering pump, p. 38
42—Low cost preset counter, p. 42
44—Bellows flow transmitter, p. 44
48—Si strain gage pressure sensor, p. 48
59—Smallest Gray magnetic encoder, p. 59
86—High performance accelerometer, p. 86
119—Magnetic flowmeter transmitter, p. 118
192—Temperature, pressure sensors, p. 192
203—High frequency galvanometer, p. 203
208—Accurate, two-speed synchro, p. 208
209—Two-speed synchro-transmitter, p. 209
211—Semiconductor strain gage, p. 211
213—Semiconductor pressure sensor, p. 213
215—Radiation tracking transducer, p. 215
245—Strain gage pressure sensor, p. 245
247—Woven temperature detector, p. 247
252—Hall effect pickups, p. 252
255—Shaft angle converter, p. 255

FIRST CLASS
PERMIT No. 64
NEW YORK, N. Y.

BUSINESS REPLY MAIL
No Postage Stamp Necessary If Mailed In The United States

POSTAGE WILL BE PAID BY

McGRAW-HILL PUBLISHING CO., Inc.

CONTROL ENGINEERING

330 WEST 42nd STREET

NEW YORK 36, N. Y.

261—Crystal accelerometers, p. 261
273—Shaft-to-digital encoders, 2nd cover
274—Variety of pancake synchros, 3rd cover
301—Line of solid state sensors, p. 258
303—Fast digital synchro, p. 260
304—Sound pressure microphones, p. 261
305—Accurate pressure pickup, p. 262
307—Uncooled IR detector, p. 263

New Products

325—Tiny cryogenic sensors, p. 198
326—U-scan shaft encoder, p. 200
327—Light beam pickoff pot, p. 200
328—Transparent end cap synchros, p. 200
329—Portable pressure standard, p. 200
330—Silicon photosensors, p. 200
331—Sealed pickup coils, p. 202

Catalogs and Bulletins

414—RF metal detectors, p. 243
415—Pneumatic transmitter, p. 243
418—Single turn potentiometers, p. 243

5. RELAYS, SWITCHES, AND CONTROLLERS

Advertisements

14—Reliable line of relays, p. 14
16—Sealed dc relays, p. 16
20—Accurate, low cost pressure switch, p. 20
52—Miniature rotary stepping switch, p. 52
69—Proportional temperature controller, p. 69
93—Compact controllers, indicators, p. 92
94—Wire contact relay, p. 94
100—Electronic counters, controllers, p. 100
104—Tailormade limit switches, p. 104
113—Compact latching relay, p. 113
199—Four-pole power control relays, p. 199
204—8 to 16-position switches, p. 204
226—Compact dry reed relays, p. 226
227—Ultrasonic level control, p. 227
231—Indicating temperature controls, p. 231
236—Magnetic and reversing contactors, p. 236
242—Low priced temperature control, p. 242
249—Time delay relay, p. 249
262—Mercury relay manual, p. 262
272—Hg-to-Hg contact relays, p. 272
292—Capacitance level control, p. 250
297—Sensitive polarized relay, p. 255

New Products

332—Sensitive diaphragm switches, p. 202
333—Adjustable programmer, p. 202
334—Rugged, sensitive relay, p. 203
335—Subminiature pressure switch, p. 203
337—Photoelectric scanner relay, p. 204
338—Wide range hydraulic switch, p. 204
339—Sensitive dc relays, p. 206
340—Material level control, p. 206
341—Half crystal can relay, p. 206

Catalogs and Bulletins

409—Space saving relay, p. 241

6. POWER SUPPLIES

Advertisements

31—Industrial thermoelectric converter, p. 30
112—Static power inverters, p. 112
205—Constant current supply, p. 205
214—Line, load regulated unit, p. 214
253—Stable transistorized source, p. 253
294—Dc-dc, dc-ac dynamotors, p. 252

New Products

342—Modular regulated units, p. 206
343—Si circuitry supply, p. 206
344—Production test unit, p. 206
345—Low voltage models, p. 206
346—Guaranteed stability unit, p. 206
347—Standby power source, p. 206

Catalogs and Bulletins

403—Regulated power units, p. 239
416—Constant voltage dc source, p. 243

ADVERTISEMENTS — *Mail Before December 1, 1961*

1	15	29	43	57	71	85	99	113	127	141	155	169	183	197	211	225	239	253	267	281	295
2	16	30	44	58	72	86	100	114	128	142	156	170	184	198	212	226	240	254	268	282	296
3	17	31	45	59	73	87	101	115	129	143	157	171	185	199	213	227	241	255	269	283	297
4	18	32	46	60	74	88	102	116	130	144	158	172	186	200	214	228	242	256	270	284	298
5	19	33	47	61	75	89	103	117	131	145	159	173	187	201	215	229	243	257	271	285	299
6	20	34	48	62	76	90	104	118	132	146	160	174	188	202	216	230	244	258	272	286	300
7	21	35	49	63	77	91	105	119	133	147	161	175	189	203	217	231	245	259	273	287	301
8	22	36	50	64	78	92	106	120	134	148	162	176	190	204	218	232	246	260	274	288	302
9	23	37	51	65	79	93	107	121	135	149	163	177	191	205	219	233	247	261	275	289	303
10	24	38	52	66	80	94	108	122	136	150	164	178	192	206	220	234	248	262	276	290	304
11	25	39	53	67	81	95	109	123	137	151	165	179	193	207	221	235	249	263	277	291	305
12	26	40	54	68	82	96	110	124	138	152	166	180	194	208	222	236	250	264	268	292	306
13	27	41	55	69	83	97	111	125	139	153	167	181	195	209	223	237	251	265	269	293	307
14	28	42	56	70	84	98	112	126	140	154	168	182	196	210	224	238	252	266	280	294	308

NEW PRODUCTS & BULLETINS

309	320	331	342	353	364	375	386	397	408	419	430	441	452	463
310	321	332	343	354	365	376	387	398	409	420	431	442	453	464
311	322	333	344	355	366	377	388	399	410	421	432	443	454	465
312	323	334	345	356	367	378	389	400	411	422	433	444	455	466
313	324	335	346	357	368	379	390	401	412	423	434	445	456	467
314	325	336	347	358	369	380	391	402	413	424	435	446	457	468
315	326	337	348	359	370	381	392	403	414	425	436	447	458	469
316	327	338	349	360	371	382	393	404	415	426	437	448	459	470
317	328	339	350	361	372	383	394	405	416	427	438	449	460	471
318	329	340	351	362	373	384	395	406	417	428	439	450	461	472
319	330	341	352	363	374	385	396	407	418	429	440	451	462	473

REPRINTS

474	485	496	507
475	486	497	508
476	487	498	509
477	488	499	510
478	489	500	511
479	490	501	512
480	491	502	513
481	492	503	514
482	493	504	515
483	494	505	516
484	495	506	517

Name _____ *Title* _____

Company _____

Address _____ *City* _____ *Zone* _____ *State* _____

7. ACTUATORS AND FINAL CONTROL ELEMENTS

Advertisements

17—Long life four-way solenoid valve, p. 17
47—Gas servos and systems, p. 47
51—High pressure temperature valve, p. 51
54—Split-body valves, p. 54
65—Valve series for low flows, p. 65
71—Control valves, level controllers, p. 70
89—Dc torque motors, p. 89
90—Velocity damped servomotors, p. 90
106—2 and 3-way solenoid valves, p. 105
229—Accurate dry feeder, p. 229
230—High speed stepper motor, p. 230
234—Size 8 servomotors, p. 234
244—Aerospace vehicle controls, p. 244
251—Servomotor data book, p. 251

New Products

348—Low power solenoid, p. 208
349—Oil sealed timer motor, p. 209
350—Small gear motors, p. 209
351—Light duty drive, p. 209
352—Simplified piggyback valves, p. 209
353—Electrothermal actuator, p. 209

Catalogs and Bulletins

402—Sliding gate regulators, p. 239
408—Rotary air pump selector, p. 241
413—Industrial valve line, p. 243

8. COMPONENT PARTS

Advertisements

19—High rated flag-type SCR's, p. 18
41—150-mw MADT for computers, p. 41
53—Noninverting dc amplifier, p. 53
57—Premium line of rectifiers, p. 57
64—High force hydraulic springs, p. 64
74—Compact modular memory, p. 74

(Continued on Page 225)

ADVERTISEMENTS — *Mail Before December 1, 1961*

1	15	29	43	57	71	85	99	113	127	141	155	169	183	197	211	225	239	253	267	281	295
2	16	30	44	58	72	86	100	114	128	142	156	170	184	198	212	226	240	254	268	282	296
3	17	31	45	59	73	87	101	115	129	143	157	171	185	199	213	227	241	255	269	283	297
4	18	32	46	60	74	88	102	116	130	144	158	172	186	200	214	228	242	256	270	284	298
5	19	33	47	61	75	89	103	117	131	145	159	173	187	201	215	229	243	257	271	285	299
6	20	34	48	62	76	90	104	118	132	146	160	174	188	202	216	230	244	258	272	286	300
7	21	35	49	63	77	91	105	119	133	147	161	175	189	203	217	231	245	259	273	287	301
8	22	36	50	64	78	92	106	120	134	148	162	176	190	204	218	232	246	260	274	288	302
9	23	37	51	65	79	93	107	121	135	149	163	177	191	205	219	233	247	261	275	289	303
10	24	38	52	66	80	94	108	122	136	150	164	178	192	206	220	234	248	262	276	290	304
11	25	39	53	67	81	95	109	123	137	151	165	179	193	207	221	235	249	263	277	291	305
12	26	40	54	68	82	96	110	124	138	152	166	180	194	208	222	236	250	264	268	292	306
13	27	41	55	69	83	97	111	125	139	153	167	181	195	209	223	237	251	265	269	293	307
14	28	42	56	70	84	98	112	126	140	154	168	182	196	210	224	238	252	266	280	294	308

NEW PRODUCTS & BULLETINS

309	320	331	342	353	364	375	386	397	408	419	430	441	452	463
310	321	332	343	354	365	376	387	398	409	420	431	442	453	464
311	322	333	344	355	366	377	388	399	410	421	432	443	454	465
312	323	334	345	356	367	378	389	400	411	422	433	444	455	466
313	324	335	346	357	368	379	390	401	412	423	434	445	456	467
314	325	336	347	358	369	380	391	402	413	424	435	446	457	468
315	326	337	348	359	370	381	392	403	414	425	436	447	458	469
316	327	338	349	360	371	382	393	404	415	426	437	448	459	470
317	328	339	350	361	372	383	394	405	416	427	438	449	460	471
318	329	340	351	362	373	384	395	406	417	428	439	450	461	472
319	330	341	352	363	374	385	396	407	418	429	440	451	462	473

REPRINTS

474	485	496	507
475	486	497	508
476	487	498	509
477	488	499	510
478	489	500	511
479	490	501	512
480	491	502	513
481	492	503	514
482	493	504	515
483	494	505	516
484	495	506	517

Name _____ *Title* _____

Company _____

Address _____ *City* _____ *Zone* _____ *State* _____

Postage Will be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY MAIL
First Class Permit No. 43, (Sec. P. L. & R.) Ridgefield, Conn.

Reader Service Department 1 (9/61)

CONTROL ENGINEERING
P. O. Box 623
Ridgefield, Conn.

For Information on Advertisements and Editorial Items

1. *Circle number on card that coincides with key number listed at bottom or adjacent to item of interest.*
2. *Fill in your name, title, company, and address.*
3. *Mail card immediately.*

Postage Will be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY MAIL
First Class Permit No. 43, (Sec. P. L. & R.) Ridgefield, Conn.

Reader Service Department 3 (9/61)

CONTROL ENGINEERING
P. O. Box 623
Ridgefield, Conn.

ORDER ARTICLE REPRINTS FROM THIS LIST

- *Circle reprint numbers on card for single copies. Write Reprint Dept. for multiple copies.*
- *See page 260 for descriptions of reprints.*
- *Don't send cash, we will bill you later.*

513—Measuring With Solid State Transducers, 50 cents
512—Ready Reference Data Files—IV, 50 cents (see also 500, below)
511—Industrial Process Chromatographs, 50 cents
510—The Use of Digital Computers (an old reprint with valuable content), $3.00
509—Applying Incremental Servos for Control, 65 cents
508—Transistor Switches for Industrial Service, 65 cents
507—Tips on the Use of Electromechanical Relays, 65 cents
506—Adaptive Control Systems, 50 cents
505—Optimizing Relay Servos, 50 cents
504—System Characteristics of Guidance Techniques, 65 cents
503—Stream Analyzer Dynamics, 40 cents
502—Survey of Dynamic Display Techniques, 50 cents
501—Six Transducers for Precision Position Measurement, 30 cents
500—Ready Reference Data Files—I, II, III, $1.35
499—Ready Reference Data Files—III, 60 cents
498—Ready Reference Data Files—II, 50 cents
497—Ready Reference Data Files—I, 50 cents
496—How to Specify Instrument Accuracy, 40 cents
494—How to Use the Root Locus in Control Design, 45 cents
489—Fundamentals of Multivibrators, 45 cents
488—A Roundup of Control System Test Equipment, 60 cents
487—Survey of Ac Adjustable Speed Drives, 50 cents
486—A New Way to Select the Best Control Valve, 50 cents
485—Fundamentals of Tie-Motor Control, 30 cents
483—Economics in Control, 50 cents
480—Applying Control Timers, 50 cents
478—Servo Modulators, 65 cents
477—Basic Data on Process Control Systems, 50 cents
476—Three Ways to Simulate Dead Time, 15 cents

Equipment Index

(Continued from page 223)

83—Precision servo components, p. 83
95—Si planar single chip circuits, p. 95
109—High current SCR's, p. 108
189—Integrator amplifier, p. 189
190—Twin contact dc-ac choppers, p. 190
196—Ground-thread ball screws, p. 196
201—Computer switching devices, p. 200
210—Germanium power transistor, p. 210
217—Diffused Si microdiodes, p. 217
220—High density terminal block, p. 220
223—Passive squaring element, p. 223
241—Size 5 component line, p. 241
254—Bidirectional counting unit, p. 254
256—Electronic parts catalog, p. 256
286—Solid state operational amp, p. 232
287—Welded diaphragm bellows, p. 235
288—Lightweight telephone handset, p. 240
289—Quick connecting plugs, jacks, p. 242
293—SCR phase shift control package, p. 251
295—Sensitive bistable amplifier, p. 252
296—Solid state t'cple reference, p. 254
308—Si voltage references, p. 217

New Products

354—Electrical limit stop, p. 211
355—SCR control device, p. 211
356—Two-position Ge switch, p. 213
357—Ultrasmall flip-flop, p. 213
358—Inexpensive SCR gate, p. 213
359—Signal conditioning units, p. 213
360—Fast modular memory, p. 213
361—Ferrite memory element, p. 215
362—Stable millivolt discriminator, p. 215

Catalogs and Bulletins

404—Digital modules, p. 239
407—Rotary component line, p. 241

9. ACCESSORIES AND MATERIALS

Advertisements

6—Thermocouple alloys manual, p. 6
10—Lapped laser rubies, p. 10
46—Gas chromatography tubing, p. 46
67—High resolution 'scope camera, p. 67
82—Full line of magnetic tapes, p. 82
103—Rectifier transient control, p. 103
194—Square root calculator, p. 194
238—Custom designed chart papers, p. 238
258—High speed tape rewinder, p. 258
259—Heat sensitive chart folder, p. 259
302—Accurate chart papers, p. 259

New Products

363—Surge protection device, p. 215
364—Improved cooling fan, p. 216
365—LVDT output converter, p. 216

CONTROL BITS

Automatic controls for a hydrofoil ship will be developed by Autonetics Div., North American Aviation. U. S. Navy awarded the contract to develop a control system that can respond rapidly and can hold down vertical accelerations in waves up to 12 ft high.

•

First silicon controlled rectifier circuitry in the steel industry is controlling speeds on the 16-stand rod and bar mill at the Gary Works of United States Steel. The SCR's supply field excitation for generators and speed regulation for motors.



"a complete, low-priced flow-control system in this cabinet?"

"yep . . . and with rate-of-flow indication, totalization and 2% accuracy!"

But, that's not the complete story on the Hays Model 371 Veritrol—it handles fluids like molasses, oils, acids, etc. . . . it uses the proved positive displacement meter . . . it can be used in the blending of two miscible fluids.

Get the complete story in specification B347/371

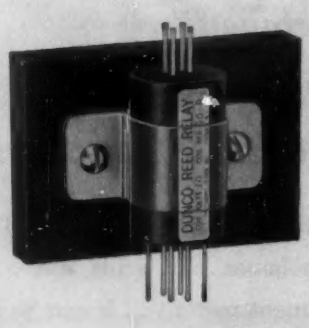
THE hays CORPORATION • MICHIGAN CITY, INDIANA

CIRCLE 225 ON READER SERVICE CARD



. . . for maximum reed relay compactness, contacting versatility and mounting convenience

Dunco encapsulated units bring you dry reed relays in their most compact, convenient form for either panel or printed board wiring. Five encapsulated types, 1- to 20-poles, provide any needed normally-open and normally-closed contact combination. Break-Make action is available to assure *non*-overlapping of contact closures. Multi-coil units can be supplied. Write for Dunco Reed Relay Data Bulletin RR-2 to: STRUTHERS-DUNN, Inc., Pitman, N.J.



Dunco 4-pole reed relay panel mounted with aluminum-end Plastostrap. Relays are also suited for printed board wiring.

S-D

STRUTHERS-DUNN

5,348 Relay Types

Sales Engineering offices in: Atlanta • Boston • Buffalo • Charlotte • Chicago • Cincinnati • Cleveland Dallas • Dayton • Denver • Detroit • High Point • Kansas City • Los Angeles • Montreal • New York Orlando • Pittsburgh • St. Louis • San Carlos • Seattle • Toronto • Export: Langguth-Olson Co., New York

226 CIRCLE 226 ON READER SERVICE CARD

WHAT'S NEW

(Continued from page 42)

Burroughs Wins 425-L Sweepstakes

WASHINGTON—

Burroughs Corp. of Detroit will be system hardware contractor on the data processing system to be installed at the North American Air Defense Command's underground combat operations center at Colorado Springs. The system, whose proposal was numbered 425-L, will tie together information about the detection of approaching bombers and ICBM's, decisions on countermeasures, and control over the counteractions.

A high speed computer will receive inputs from many warning systems (such as BMEWS, Ballistic Missile Early Warning System), calculate a summary of the tactical situation, and then display the results to NORAD commanders. With the computer assimilating large volumes of data, officers will be able to execute decisions rapidly, based on latest information.

Working with Burroughs as associate contractors are the Mitre Corp. and Systems Development Corp. who will handle system programming.

The race for 425-L has been under way for almost three years, with every company in the computer business bidding for the job. Total cost for the data processing and display system has been estimated at $60 million. About $12 million will be earmarked for R&D this year.

Growing Instrument Market Seen in Greece

As Greece moves toward full membership in the European Economic Community, many companies engaged in selling on the Continent are turning with increased interest to the little Mediterranean country. Also, some U.S. firms who have been selling in Greece are worrying about the safety of their markets.

Manufacturing and processing industries, while small, rank second after agriculture as Greece's source of income. Industry has grown steadily in the postwar years, and the production index has doubled during 1950-58. Outlets for instrumentation products are to be found in textiles, food processing, tobacco, chemicals, wearing apparel, metalworking, and woodworking industries, which account for 85 percent of Greece's industrial production. Also, a five-year development plan, announced in

A NEW ADDITION TO THE SONAC LINE

POSITIVE ULTRASONIC LEVEL CONTROL



The components of Sonac (sensor actual Size)

Now, two new ultrasonic sensors, especially for level control have been added to the Delavan line of SONAC sensing and switching devices.

The single sensor system is recommended for liquid level control and the double sensor system for dry level control.

Control is maintained by installing the SONAC sensor through the wall of the vat, bin or hopper. When the oscillation on the face of the sensor is dampened or impeded by the material being sensed, the signal to the control unit changes, activating a relay.

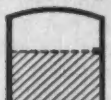


FIG. 1—LIQUID LEVEL (One Sensor)



FIG. 2—DRY LEVEL (Two Sensors)

For level control, SONAC is accurate to .005" and has a response time of 25 milliseconds. Performance of the sensor does not deteriorate with age.

The level control uses to which SONAC can be applied are virtually unlimited. It is not affected by the viscosity*, specific gravity, conductivity, or capacitance of the material being sensed. Temperature or pressure changes of the material do not alter its performance. False signals are eliminated because SONAC may be adjusted so as not to sense steam, foam, or vapors.

*Viscosity may affect response time.

Canadian Representative:

KNOWLES & FOSTER (North America) Ltd.

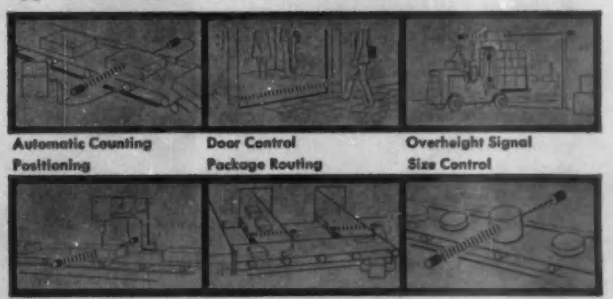
708 Terminal Bldg., Toronto 1, Ontario, Canada

A

SONAC is extremely rugged. Sensors are type 304 stainless steel. The electronic components in the sensors are hermetically sealed and will withstand pressures to 2000 psi and temperatures from −425° F. to +450° F. They are immune to shock, vibration or mechanical damage.

The control is a compact unit 5" x 5" x 5" and features transistor circuitry. Power consumption is one watt and the unit will operate in temperature ranges from 40° F. to 135° F.

Here's how SONAC can be used for sensing and switching applications other than level control.



Automatic Counting Positioning | Door Control Package Routing | Overheight Signal Size Control

There are dozens of applications for SONAC *single and double sensor units. Let it go to work for you now, write:*

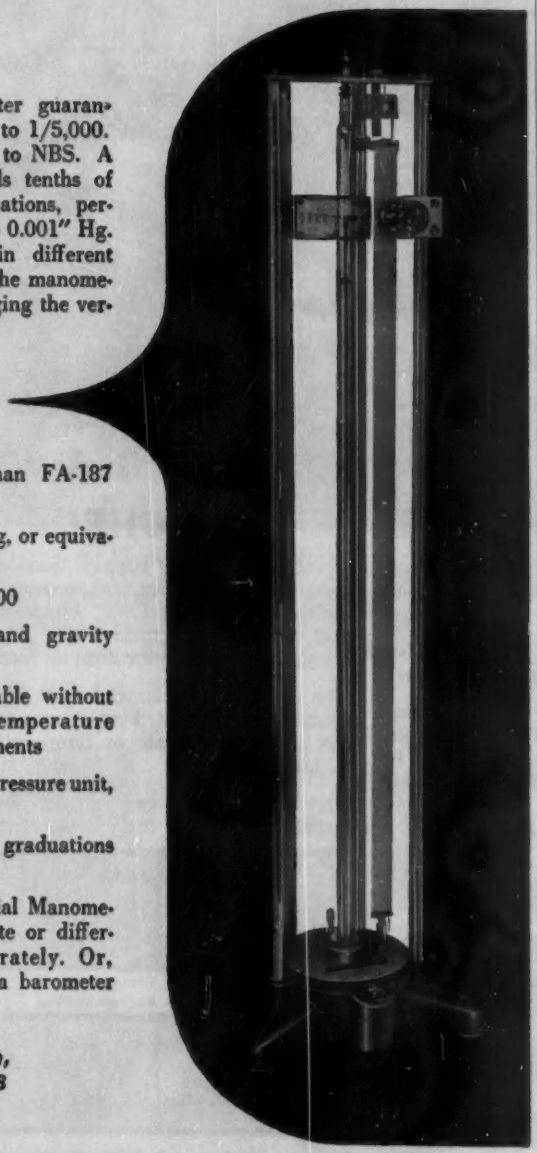
DELAVAN Manufacturing Company

WEST DES MOINES, IOWA

CIRCLE 227 ON READER SERVICE CARD

GET W&T U-Tube accuracy with Fast, Direct Readout .. PRECISION MERCURIAL MANOMETER

The FA-187 Manometer guarantees readings accurate to 1/5,000. Accuracy is traceable to NBS. A magnetic vernier reads tenths of the main scale graduations, permits direct readings to 0.001" Hg. Five vernier scales in different units allow changing the manometer scale without changing the vernier.



The Wallace & Tiernan FA-187 Manometer also gives:

- ★ Range: 800 mm. Hg, or equivalent
- ★ Sensitivity: 1/25,000
- ★ Full temperature and gravity compensation
- ★ Scales interchangeable without recalibration of temperature and gravity adjustments
- ★ Calibration in any pressure unit, or equivalent
- ★ One or two sets of graduations on a single scale

Use the W&T Mercurial Manometer to measure absolute or differential pressures accurately. Or, quickly convert it to a barometer on the job.

For more information, write Dept. A-134.28

WALLACE & TIERNAN INC.
25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

228 CIRCLE 228 ON READER SERVICE CARD

WHAT'S NEW

1959, calls for expansion of the state-owned electric power system.

• **All imports**—The market for American-made instruments stands to grow in this growing industrial economy—if U.S. producers sell it—since there is no Greek instrument industry. The present size of the Greek instrument market, some tips on what industries should become important, and some guides to selling in Greece are contained in an 11-page publication issued early this summer by the U.S. Dept. of Commerce.

The Scientific, Motion Picture, and Photographic Products Div. of the department's Business and Defense Services Administration notes that gaging the Greek instrument market is not always easy. Official Greek instrument import figures—which represent total consumption—have been compiled only up to 1959. They list imports of instruments worth about $4 million a year in 1956-59. But by usual U.S. classifications, these figures would be much higher.

Figures now compiled by the department show that West Germany is Greece's principal supplier of instrumentation products (as it is for all goods), followed by the United Kingdom, Switzerland, and the U.S. In the field of industrial and process instruments, the U.K. leads, followed by W. Germany and the U.S.

• **Price disadvantage**—U.S. instrument exports to Greece amounted to about $1 million in 1960—according to U.S. data—which is more than twice the total of any of the previous four years. Despite this healthy growth and the excellent reputation American-made instruments enjoy in Greece, the department concludes that U.S. sales are severely handicapped by higher prices compared with the West German and British competition. The department recommends that quicker progress could be made in this market by U.S. suppliers if they used better promotional methods, accepted smaller orders, and offered more liberal servicing and payment plans.

Copies of the publication, "Instrumentation in Greece", are available from the Dept. of Commerce (Washington 25, D. C.) at $0.10 each.

UK Seeks Common Market Role; Rest of EFTA to Follow

LONDON—

To a chorus of jeers from members of Parliament—even from some of his own party—Prime Minister Harold Macmillan late in July announced that

he had taken steps to start negotiations with the European Economic Community leading to Common Market membership for Britain. On the Continent, most of the other six members of the European Free Trade Association indicated that they would be likely to follow close behind.

The move is far from unexpected. Few observers would have bet against the British bid in the face of booming prosperity in the Common Market countries (see CtE, July '61, p. 30). Negotiations are expected to be difficult and protracted.

Computers Pace 1st Quarter Business Machine Exports

Electronic computers helped boom U.S. business machine exports to almost $78 million in the first quarter of this year, a total 74 percent higher than that in the same period of 1960. Exports of computers and related equipment for business use jumped a whopping 235 percent from last year to almost $28 million, or 36 percent of the total business machine exports. They accounted for nearly half the dollar increase. These figures were reported by the Business and Defense Services Administration of the Dept. of Commerce.

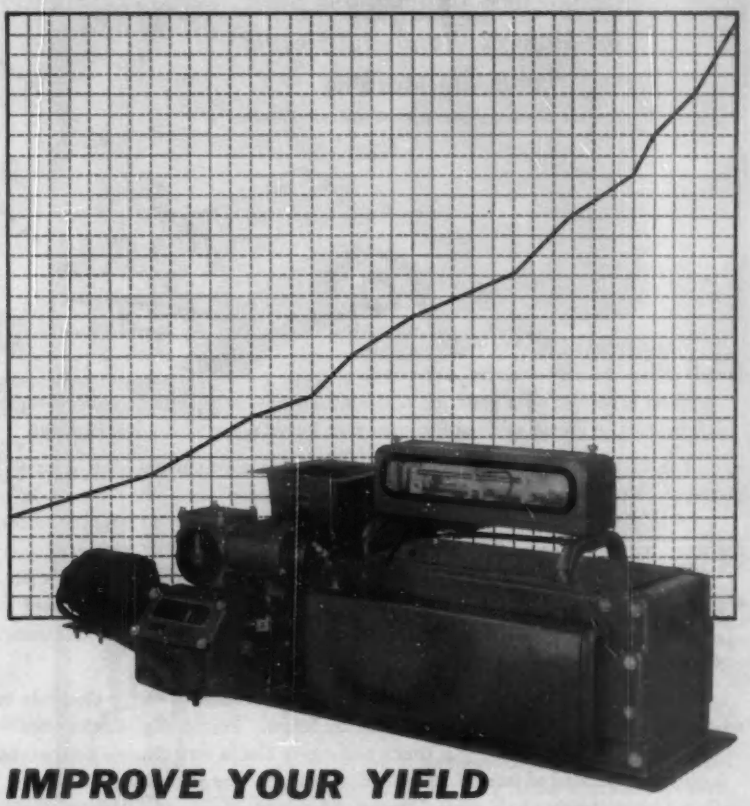
A year ago, electronic computers represented just 19 percent of the total export picture, while punched card equipment, now off to 20 percent, accounted for 22.5 percent of the total.

Japan, with 15.4 percent of the total, was the best single customer country in the first three months of '61, but the greatest percentage increase was shown in exports to South America—up 133 percent. Nearly 47 percent of the dollar value in business machines went to Europe. Of this, Common Market countries bought 62 percent and the Outer Seven states, 36.5 percent.

Value of Measuring Instrument Shipments Up 14 Percent

Figures released by the Dept. of Commerce in July showed a 14-percent increase in the dollar value of electrical measuring instruments shipped by U.S. manufacturers in the first three months of this year. The number of these devices shipped was off by 2 percent, however.

The department's Business and Defense Services Administration said that shipments of 897,960 units were valued at $32.5 million in the first quarter of this year, compared with totals for the same period of 1960 of 916,436 units with a net worth of $28.5 million. The increase in value was brought about by the 23-percent



IMPROVE YOUR YIELD WITH 99% FEEDING ACCURACY...

THE W&T MERCHEN FEEDER

If you need accurate control of dry, free flowing materials to keep process yields high, count on the W&T Merchen Feeder. The Merchen controls dry flow to a hairsbreadth, hour after hour.

Pick any minute any time in your run. Pick one at high capacity, another at low capacity. The Merchen holds accuracy to ±1% from minute to minute . . . stretches the minutes into hours of precise feeding. You solve tough feeding and continuous-blending problems, get sure quality control.

Accuracy comes from sensitivity. And a change of just one ounce in a 63-pound belt load actuates the Merchen's control mechanism. It responds instantly. Accuracy is assured.

This versatile Wallace & Tiernan Feeder has other advantages: It's a straight gravimetric feeder; it feeds and controls other equipment; or it feeds in proportion to any 3-15 psi signal. Corrosion-resistant construction lets it handle most chemicals. And even the largest model occupies less than 3 x 5 feet of floor space.

For more information, write Dept. M-64.28.

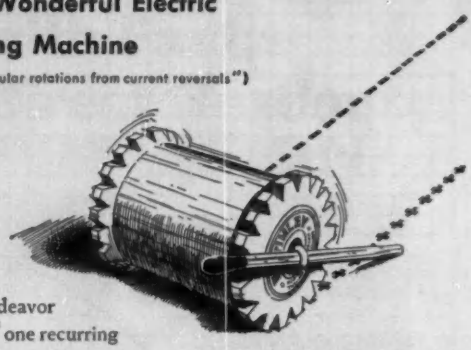
WALLACE & TIERNAN INC.

25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

CIRCLE 229 ON READER SERVICE CARD 229

new applications for Sigma's Wonderful Electric Stepping Machine

(Or, "Discrete ratchetless angular rotations from current reversals")



In the broad field of endeavor loosely called "instrumentation," one recurring problem is how to do a good job of converting *pulses*—or current reversals—into *shaft positions*. A dandy solution for present or future reference follows forthwith.

The *Cyclonome*® is a high speed *magnetic* stepping motor, whose shaft stays in one of 20 stable positions until a current reversal comes along; then it turns 18° (±¼°). Because the precise incremental rotation is due solely to magnetic forces, the wear, noise, slowness, short life and high input power of ratchet-and-pawl devices are completely avoided. The Cyclonome will step up to 400 times per second (20 rps), using ¼ to 40 watts depending on the speed and what's hitched to the shaft as well. Here are some current (reversing) examples of jobs being done by Cyclonomes.

In response to voltage variation, a Cyclonome precisely moves the electrode in an automatic welder to maintain a constant arc length. "Positioning" Cyclonomes also drive magnetic tape, strip charts and movie film in very discrete amounts to a particular section of interest, on pulsed commands. The motors are also expert knob twiddlers, turning gain controls on amplifiers and scopes and tuning receivers for automatic band sweeps. An electric utility uses a Cyclonome motor driving a wiper arm around a printed circuit switch deck (see Cycloswitch® illustration) to indicate tap positions on remotely located tap changing transformers; in a medical research application, a Cycloswitch monitors blood temperatures at several points in the patient's circulatory system.

As "pulse translators," Cyclonomes are: measuring fuel consumption or liquid flow from a pulse-generating rotor inside a pipe; remotely controlling mix in a petroleum blending machine; counting traffic by converting input pulses into successive positions of memory code discs; counting the numerical difference between pulses from two sources, in an "impulse difference relay;" indicating time as a "clock mechanism" in a precise time comparator.

In some cases we've done the "packaging," with due regard for Cyclonome input, output, coupling, and compatibility of components with our motor.

We'd be glad to tackle your problem this way, or just sell you the motor with almost no questions asked. Give it some thought, particularly for unattended field equipment and where its ability to eliminate other bugs and headaches can mean a simpler, less costly overall answer.

If that's too much to ask, just give Sigma some thought.



Unidirectional Cyclonome



Bidirectional Cyclonome



Series 9C Cycloswitch

SIGMA

SIGMA INSTRUMENTS, INC.

69 PEARL ST., SO. BRAINTREE 85, MASS.

230 CIRCLE 230 ON READER SERVICE CARD

increase in the volume of the more costly direct-acting recording, self-balancing, and oscillographic instrument categories. At the same time the less expensive panel, switchboard, and portable unit sales decreased to account for the total drop.

RCA, Bull at Work on Joint Research, Sales Agreement

Radio Corp. of America and the French computer builder, Compagnie des Machines Bull, are in the process of reaching a joint sales, licensing, and technical information exchange agreement. According to RCA in New York, representatives of the two firms have agreed in principle to a pact calling for the sale of data processing equipment by RCA to Bull, the establishment of nonexclusive licenses, and the setting up of technical assistance arrangements.

No further details were available since the agreement still must meet the approval of the two companies' boards and of U.S. and French government agencies.

Unofficial Paris sources indicate that the agreement will give Bull access to RCA electronics research results across the board, but Bull has denied that it plans expansion outside the data processing field.

In addition, Bull has revealed that negotiations are well under way with another American company—not RCA—for the sales of Bull machines in the U.S. Bull had a sales agreement with Remington Rand Univac; the pact expired last year. The French firm then set up its own subsidiary but now is said to want another tieup with an American company to bolster its U.S. sales effort. More than half of Bull's sales ($20.6 million in the first five months of 1961—up to 66 percent over last year) were exports.

Shift Results in New Groups at GE's Defense Systems

Four new operations have evolved out of a realignment in the Defense Systems and Heavy Military Electronics Depts. of General Electric Co. Richard L. Shetler, general manager of the Syracuse, N. Y., based Defense Systems Dept. has announced the new sections, Specialty Devices Operation, Engineering Operation, Information and Control Systems Product Section, and Instrumentation and Guidance Product Section.

The Specialty Devices Operation

5 REASONS FOR SPECIFYING U.E. INDICATING TEMPERATURE CONTROLS

* **HIGH SENSITIVITY...** on-off differentials from ± .5° F with excellent repeatability

* **LOW COST . . .** list prices from $35.00 with generous quantity discounts

* **EASY MAINTENANCE . . .** thermal assemblies quickly replaced in the field with no loss of calibration accuracy

* **PROVEN DEPENDABILITY...** reliable liquid-filled measuring systems combined with simple service-proven components for accurate performance and long life

* **GREATER VERSATILITY...** many styles, ranges, sensing elements and switch characteristics permit hundreds of "custom-built" combinations

ALL PURPOSE

-150° to +650° F

A sensitive wide range unit with control point accuracy equivalent to individually calibrated instruments. 10" rotating scale permits unusual readability and close settings. Available with dual switches for controlling two independent circuits.



E 32N



E 36N

LOW COST... (800 Series) -150° to +650° F
Short dial spans of 50 to 200° F permit compact design only slightly higher in price than non-indicating controls. Available with dual switches.

HIGH TEMPERATURE . . . (900 Series) 0° to +1000°F
A NEW high temperature series with rugged stainless steel mercury filled thermal systems.

For the USUAL or UNUSUAL application, United Electric offers quality controls at economical prices.



E 65N

SPACE SAVING... -150° to +650° F
Skeleton design permits direct incorporation into equipment—saving cost of enclosure. Many models with dial spans of 50 to 200°F. Available with face plate for panel mounting.



E45N

SPECIAL PURPOSE... -150° to +1000°F
Shown here is a typical Special Purpose control used on medical equipment, such as baby incubators, etc. WHAT IS YOUR REQUIREMENT? Chances are one of our standard controls will satisfy your needs. If not, we'll put our 30 years' experience to work for you on special designs.

UNITED ELECTRIC CONTROLS CO.
85 School Street
Watertown 72, Massachusetts
SUBSIDIARIES
United Electrical Controls (Canada) Ltd. | United Sensor & Control Corp.
O'Connell Avenue Dorval, Quebec | Box 149 Glastonbury, Conn.

Write TODAY for complete specifications and price information on U. E. Indicating Temperature Controls, Attention Dept. W.

NAME_____ TITLE_____

COMPANY_____

ADDRESS_____

CITY_____ STATE_____

new!

ultRelay



The Static Relay with Meter Movement Sensitivity

The ultRelay, a new solid state ultrasensitive relay with input sensitivity to 0.25 microwatt, was designed specifically for applications which previously required fragile meter movement relays. Absence of mechanical contacts, bearings and moving coils permit millions of switching cycles and freedom from failures caused by contact chatter, vibration, wear and burning.

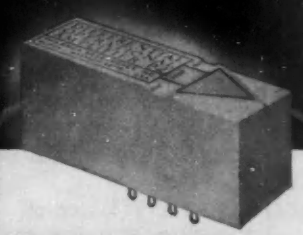
- **Input sensitivity to 0.25 microwatt D.C.**
- **Low input resistance**
- **Directly operable from thermocouple output**
- **Power amplification to 95 db**
- **60~ 115V loads to 400 watts**
- **Vibration and shock resistant**
- **No external reset circuits required**
- **Single, double or differential input options**
- **Electrical isolation between load and control**
- **Size, 3" x 3" x 3⅛"**
- **Single pole, N.O. or N.C. units available**

Send for literature

Electronics Division
AIRBORNE ACCESSORIES CORPORATION
1414 Chestnut Avenue, Hillside 5, New Jersey; MUrdock 8-0250
5456 W. Washington Boulevard, Los Angeles 16, California; WEbster 8-3227

232 CIRCLE 232 ON READER SERVICE CARD

The all-new, all solid-state Philbrick P2 amplifier



NO TUBES, NO CHOPPERS, NOTHING BUT PERFORMANCE. An ingenious arrangement of all solid-state components endows this operational amplifier with the most remarkable and versatile characteristics. *Full differential input:* truly floating with respect to ground. *No common mode error. Low input current:* typically 10^{-11} amps. *Low noise:* typically under 10 microvolts in the dc to 1 kc range. *Sub millivolt long term stability:* less than 100 microvolts drift per day. *Cool running:* typically under 330 milliwatt dissipation. *Wide band pass:* typically under 75 kc as a unity gain follower. *High open loop gain:* typically 30,000. Its output delivers 1 ma at ± 10 volts. The cast aluminum housing fits right in your hand.

Use the P2 for instrumentation, analog computation, and other applications requiring high reliability and accuracy. Take advantage of its differential inputs to perform high impedance operations. *Truly low cost:* **$210.**

SOLID STATE POWER SUPPLY PR 150. For energizing at least 10 P2 amplifiers, the PR 150 has extremely low noise, drift, and internal impedance. Regulation against load, less than 300 microvolts. It provides up to 150 ma at both plus and minus 15 volts. Price: **$285.**

Please write for further information to:

GEORGE A.
PHILBRICK
RESEARCHES, INC.

127 CLARENDON ST. BOSTON 16, MASS.
COMMONWEALTH 6-5375. TWX: BS 1032. FAX: BSN
REPRESENTATIVES IN PRINCIPAL CITIES
EXPORT OFFICE: 240 W. 17TH ST., N. Y. 11, N. Y.
TEL. CHELSEA 3-2100. CABLE: TRILRUSH

CIRCLE 286 ON READER SERVICE CARD

will deal in electronic components that use new, sophisticated fabricating techniques, such as modular component assemblies and ferrite core memory planes. The new Engineering Operation, to be headed by Roy S. Mushrush, Jr., will be responsible for radiation effects and communication systems and equipment. The operation will also support other DSD product operations in the fields of reliability, logistics, standards, documentation, and industrial design.

Command and control information intelligence equipment; air traffic control systems; and associated computing, display, and data processing equipment will be handled by the Information and Control Systems Product Section. The group will be managed by Warner R. Sinback. The Instrumentation and Guidance Product Section, under John K. Records, will deal in major defense systems, such as missile guidance systems and range safety and tracking nets.

Aerojet Launches New Space Systems Subsidiary

Aerojet-General Corp., leading rocket engine builder, has combined its Spacecraft Div. and its subsidiary Space Electronics Corp. to form a new Space-General Corp. The new subsidiary will devote its efforts to design and development of complete missile and space systems.

Dr. James C. Fletcher and Frank W. Lehan, president and executive vice-president, respectively, of Space Electronics, have been named to comparable posts in the new outfit. Currently the unit is operating out of SEC's facility in Glendale, Calif., but a new plant—part of a multimillion dollar investment program—will be built in Los Angeles and is scheduled to be ready early next year.

News of Other Companies in the Control Field

Beckman Instruments, Inc. and **Offner Electronics, Inc.** are planning a merger that would result in Offner, a Schiller Park, Ill., manufacturer of medical and electronic instruments, becoming a division of the Fullerton, Calif., company.

Laboratory for Electronics, Inc., Boston, intends to acquire Tracerlab, Inc., Waltham, Mass., to form a company with current combined sales of over $60 million a year. Approval of both boards of directors has been ob-



Non-linear problems solved by QUADRATRON®

Three ounce passive unit, developed by Douglas, replaces function-generating systems many times bigger and costlier

The Quadratron is a unique passive squaring element. It is normally used with standard D.C. operational amplifiers to generate an important class of the most useful non-linear functions. Included are the following:

SQUARE SQUARE ROOT
MULTIPLICATION SINE
COSINE TANGENT

This multi-function versatility is obtained entirely by variations in the external circuitry.

The simple, compact Quadratron has already proved its outstanding reliability in the communications, petroleum, aircraft and missiles, nucleonics, instrument and glass industries.

MODEL SPECIFICATIONS

Type P, Model D Standard
Input signal range, ±100 volts
Squaring Error, 0.4% of full scale
Current from driving source, 2.5 ma.

Type P, Model E Improved Accuracy
Input signal range, ±100 volts
Squaring Error, 0.2% of full scale
Current from driving source, 1.5 ma.

Type P, Model F for Transistorized Amplifiers
Input signal range, ±10 volts
Squaring Error, 0.2% of full scale
Current from driving source, 1.5 ma.

Douglas will supply complete details related to specific applications.

DOUGLAS

MAIL COUPON FOR FULL INFORMATION

Mr. L. M. Spencer, Douglas Aircraft Company, El Segundo, California
Please send me descriptive material relating to the QUADRATRON

NAME _____ **TITLE** _____

COMPANY _____

ADDRESS _____

CITY _____ **ZONE** _____ **STATE** _____

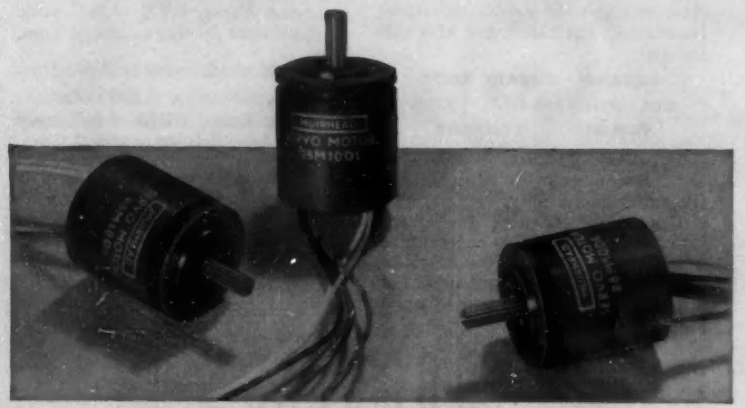
CIRCLE 233 ON READER SERVICE CARD **233**

SIZE 8 SERVOMOTORS

The Muirhead Size 8 Servomotor, only 0.84" in length, and weighing only 1.2 oz. reaches a no-load speed above 6,200 r.p.m. and produces a stalled torque of over 0.2 oz. ins. It has a torque inertia ratio exceeding 110,000 rad/sec.².

The Muirhead Size 8 is but one of a series of servomotors available up to Size 18.

Send for your copy of the latest broadsheet containing details of Muirhead Servomotors and Synchros.



MUIRHEAD

Precision Electrical Instruments

MUIRHEAD INSTRUMENTS INC., 441 LEXINGTON AVE., NEW YORK 17, N.Y., U.S.A.
Telephone: Murray Hill 2-8131
MUIRHEAD INSTRUMENTS LIMITED, STRATFORD, ONTARIO, CANADA
Telephone: 271-3880
MUIRHEAD & CO., LIMITED, BECKENHAM, KENT, ENGLAND
Telephone: Beckenham 4888 512/3

WHAT'S NEW

tained for the move. Tracerlab deals in nuclear and X-ray equipment.

International Systems Control Ltd. has been formed in Wembley, Middlesex, England, by Thompson Ramo Wooldridge, Inc. of Los Angeles and the General Electric Co. Ltd. of England. ISC will make and sell TRW's RW 300 process control computer in Europe and the Commonwealth. Prime targets: steel, power, industries.

European Computer Manufacturers Association has been formed by 18 companies manufacturing and selling data processing equipment in Europe. First president of ECMA, which will have headquarters in Geneva, is C. G. Holland-Martin of International Computers and Tabulators Ltd., England.

Datametrics, Inc. is a new firm established in Waltham, Mass., to develop pressure transducers and flow measuring instruments. The company has been formed by Hollis L. Gray, Jr., formerly with Technology Instrument Corp. Certain of TIC's proprietary products will be manufactured by Datametrics under license.

Brooks Instrument Co., Inc., Hatfield, Pa., has acquired Francisco Engineering Co., a California manufacturer of turbine flowmeters, mass flowmeters, and digital data transmission and control equipment. Francisco will be operated under the name of Hydropoise, Inc. as a subsidiary and will be moved to Scottsdale, Ariz.

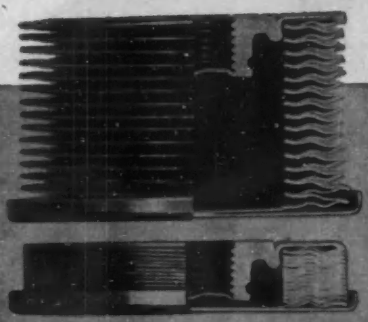
General Railway Signal Co. of Rochester, N. Y., and a Dutch subsidiary of International Telephone and Telegraph Corp., **Nederlandsche Standard Electric, Mij. N.V.** of The Hague, have formed a new company to make and sell railway signal and control apparatus. The joint venture, Algemene Sein Industrie, N.V., with headquarters at The Hague, will manufacture and sell in several countries.

Diginamics Corp. is a new company formed by former employees of Minneapolis-Honeywell's Aeronautical Div. The Minneapolis company will develop equipment for translating information between control computers and their controlled systems.

Ling-Temco Vought, Inc. became a new corporate entity on August 31 in Dallas when the merger of Ling-Temco Electronics, Inc. and Chance Vought Corp. was consummated.

WELDED DIAPHRAGM BELLOWS By METAL BELLOWS CORP.

111-1C



Lear · HONEYWELL · HONEYWELL · HORDEN

SANDERS ASSOCIATES, INC.
NASHUA, NEW HAMPSHIRE

NORTRONICS
A Division of
NORTHROP CORPORATION

Used by Leading Manufacturers of Guidance and Propulsion Systems In Aero-Space Applications

Where extreme accuracy, reliability and consistent performance are specifications . . . you can depend on the pioneers and leaders in welded metal diaphragm bellows research, engineering and manufacturing to deliver the results.

Design and manufacturing services are available in full depth from our plants on the east and west coasts.

METAL Bellows CORPORATION

108 MICA LANE, WELLESLEY HILLS 82, MASSACHUSETTS • Pacific Division: 20975 Knapp Street, Chatsworth,(L.A.) California

CIRCLE 287 ON READER SERVICE CARD



AC-DC VOLTMETER MODEL AC-100A
Accuracy . ±.05% + 5 microvolts DC
±.2% AC
(Accuracy of Reading)
Frequency Range . . . 30 cps to 10 KC
Voltage Ranges . . 0 to 1000 volts DC
.5 to 1000 volts AC
Stability . . . ±.002% for 105/125 V
(Reference) line voltage
±5 PPM/°C (+10°/+40°C.)
Price . . . $795* (Rack mounted, $815)



AC-DC CONVERTER MODEL C-100AR
Accuracy . . . ±.15% absolute/.5 to 1000 VAC
Frequency Range . . . 30 cps to 10 KC
5¼ x 19" panel for Rack Mounting
Price $455*

CALIBRATION > STANDARDS Precision

AC-DC Converter and AC-DC Voltmeter

A new Differential Voltmeter. Fully transistorized. Wider ranges both in AC and DC. More sensitivity. Uses 1 mv null detector for both AC and DC. Extremely stable. Wider frequency range — 30 cps to 10 KC. Potentiometric. Readout in 5 digits. Uses new CSC ultra-stable Zener reference standard. Priced for today's market. Convert your DC measuring system with CSC model C-100AR. Ideal for use with differential and digital voltmeters. Accurate. Stable. Solid state circuitry. Operates on 115VAC. • Low cost permits immediate conversion to AC measurements.

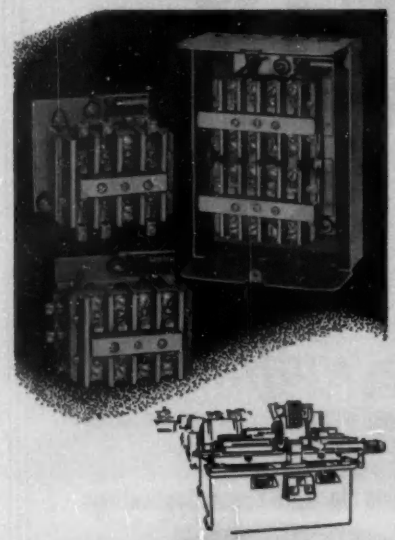
Write for detailed specifications or contact your local CSC Representative.

LOS ANGELES, *SMITH-DIETRICH SALES COMPANY* • SEATTLE-PALO ALTO, *STANLEY ENTERPRISES* • DENVER-SALT LAKE CITY, *EMF ASSOCIATES* • CHICAGO, *LOREN P. GREEN & ASSOCIATES* • WICHITA, *LAWRENCE L. HILL* • WALTHAM, MASSACHUSETTS, *GEO. GOSTENHOFER & ASSOCIATES* • SCHENECTADY, *CHARLES A. WINICK COMPANY* • NEW YORK CITY (MT. VERNON), *QED ELECTRONIC SALES, INCORPORATED* • PHILADELPHIA (LANSDOWNE), *HOLDSWORTH & COMPANY* • ARLINGTON, VIRGINIA, *THE JAY COMPANY* • ATLANTA-COCOA BEACH, *SPECIALIZED EQUIPMENT COMPANY* • CLEVELAND-DAYTON-DETROIT, *ELECTRO SALES ASSOCIATES* • EXPORT, *FRAZAR & HANSEN, LTD.* VANCOUVER-TORONTO-MONTREAL, *AVIATION ELECTRIC LTD.*

CALIBRATION > STANDARDS CORPORATION
a subsidiary of ROYAL > INDUSTRIES INC.
1025 Westminster Ave., Alhambra, Calif.
* F.O.B. ALHAMBRA, CALIF. PRICES SUBJECT TO CHANGE WITHOUT NOTICE

CIRCLE 235 ON READER SERVICE CARD

Here are rugged, reliable
COMPACT CONTACTORS
for high capacity service!



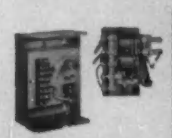
B|W

Industrial and Motor
CONTROLS

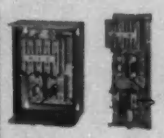
Take a good look at the B/W line of magnetic and reversing contactors and you'll get a refreshing new concept of motor control quality and value.

☐ They're small in size—simple, straightforward in design—easy to wire—and ruggedly built to give you reliable, long-life service on a wide range of high capacity control applications. All contacts are vertically mounted up front. Built-in return springs provide fast, positive breaks. Armatures travel in a straight predetermined plane to assure proper seating, quieter operation. Available in low-cost horsepower and ampere rated models to meet your special application requirements.

Other Reliable B/W Electrical Control Components



Induction Type & Electronic Relays



Magnetic Starters & Combination Starters

Custom Engineered Control Panels



Push and Pull Type A. C. Solenoids



Complete technical data available upon request—write today!

THE B|W CONTROLLER CORPORATION

2200 E. MAPLE ROAD • BIRMINGHAM, MICHIGAN

Manufacturers of Liquid Level and Industrial Motor Controls

IMPORTANT MOVES BY KEY PEOPLE

Dr. Wanlass Joins Packard Bell From Aeronutronic Post



Dr. S. Dean Wanlass has taken a post with Packard Bell Electronics as group vice-president in charge of the company's Technical Products Div., Computer Div., and partly owned Physical Sciences Corp. subsidiary. Dr. Wanlass comes to PB from a post as general operations manager of Space Systems at the Aeronutronic Div. of Ford Motor Co.

With Aeronutronic since 1956, Dr. Wanlass had served in a number of positions. Previously he headed the Navigation Dept. at Lockheed Aircraft Corp., where he was responsible for systems later used on the Polaris.

Dr. Wanlass was a member of the Systems Analysis Group at Hughes Aircraft that left several years ago to form the Ramo-Woolridge Corp.

In another move, apparently unrelated to the Wanlass appointment, the resignation of Max Palevsky, director of PB's Computer Div., was announced.

Dr. Dempsey Takes Over Honeywell Lab Direction



Dr. John N. Dempsey has become director of the Research Center of Minneapolis-Honeywell Regulator Co. and associate director of the Minneapolis-based company's over-all research activities. Dr. Dempsey succeeds Dr. Van W. Bearinger, who is now general manager of Honeywell's Semiconductor Div., as director of the center.

The 38-year old Dempsey has been assistant director of the center since last year, with specific responsibility in work with infrared, ultraviolet, ceramics, and solid state physics.

The activities he will supervise involve nearly 200 scientists and engineers in a variety of projects.

Cordiner Still Guides GE; New No. 2 and 3 Men Named

Ralph J. Cordiner, who has served as both board chairman and president of General Electric Co. since early this year, has announced a new president and executive vice-president. He has also asserted his intention to remain as chief executive officer for at least as long as he feels it necessary to improve the company's business condition. There had been some speculation that he might retire in the wake of the recent price fixing convictions handed down against GE.

As new president, Cordiner announced Gerald L. Phillipe, a 51-year old financial man who has been comptroller and principal financial officer since 1953. New executive vice-president is Cramer W. LaPierre, 57, an engineer who was vice-president and group executive in charge of the company's Electronics and Flight Systems Group.

GE's five group executives will continue to report directly to Cordiner; the company's staff group will report to Phillipe; and LaPierre will be in charge of advance planning, special business situations, and the company's technical progress.

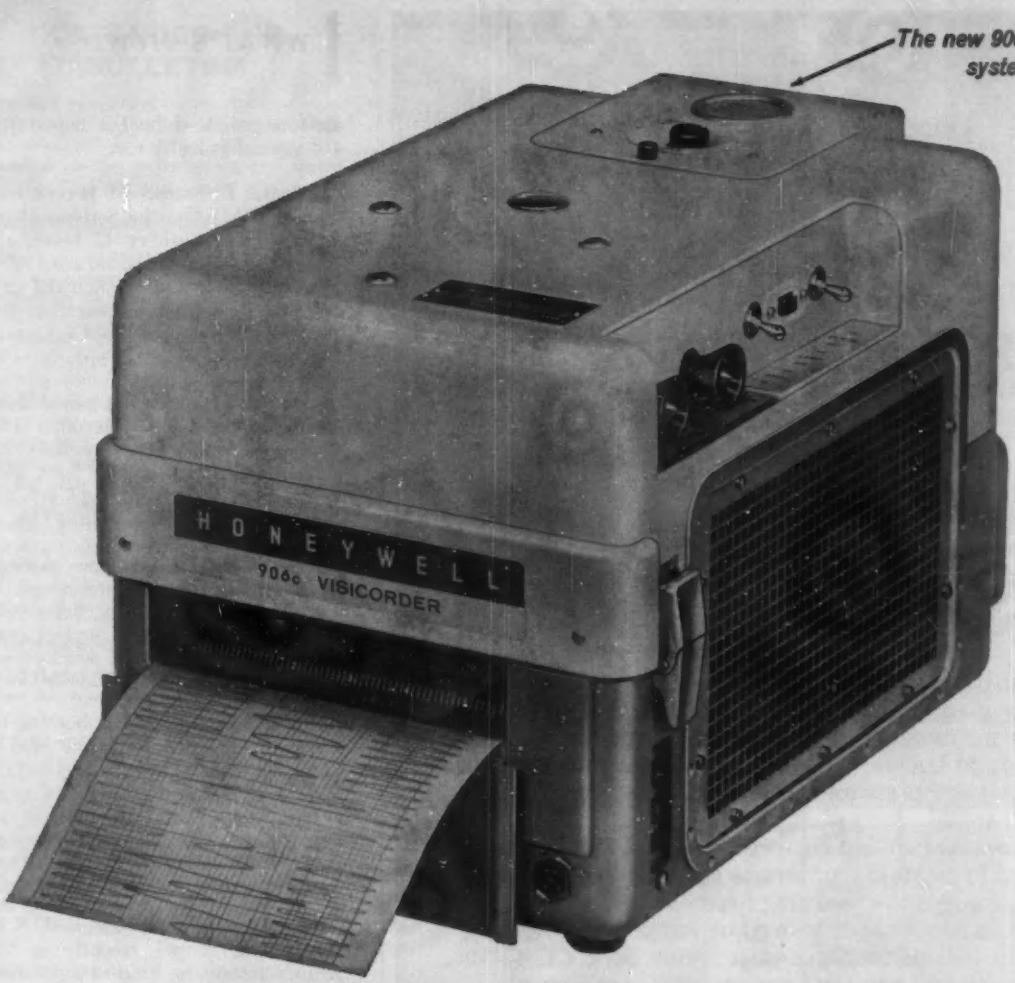
Other Important Moves

Chester W. Nimitz, Jr., has resigned from Texas Instruments, Inc. to become a vice-president of Perkin-Elmer Corp. and general manager of the Norwalk, Conn., firm's Instrument Div. Nimitz joined TI in 1957 after 21 years in the U. S. Navy.

J. V. Holdam has been elected vice-president of Dresser Industries, Inc. with the responsibility of supervising the firm's electronics activities. His activities will be concerned primarily with the Dallas-based company's HST and SIE Divs. Holdam comes to Dresser from Laboratory for Electronics, Inc., where he was vice-president. He had been a co-founder of LFE and vice-president of Tracerlab, Inc.

N. V. Petrou is the new general manager of the Air Arm Div. of Westinghouse Electric Corp. in Baltimore, Md. Petrou was formerly engineering manager of the division. He succeeds Dr. Patrick Conley who is vice-president with responsibility including the firm's new Industry Systems Dept. (see page 40).

Benjamin F. Bennet is the newly appointed manager of general industry engineering at General Electric Co.'s Industry Control Dept. in Salem, Va. He'll be responsible for product, systems, and applications engineering of electrical controls and



What's *different* about the NEW 906C VISICORDER OSCILLOGRAPH?

At first glance you may see no difference at all. Just the same functional lines and compact size that you have come to recognize in the Visicorder.

They have not changed since 1956, when the Visicorder principle of oscillography made immediate readout of high frequency data possible for the first time.

Until now, all the improvements that have maintained the Visicorder's record of leadership have been internal:

—increased capacity to 14 channels
—higher frequency response (0-5000 cps)
—simultaneously recorded grid lines
—self-starting lamp for remote operation

But the 906C has a new feature you *can* see, (look carefully at the back of the case) and one that represents still another breakthrough; a built-in flash tube timing system which not only generates its own time base, but which can also be triggered *externally*. You can, in other words, use the 906C's timing system to record time lines simultaneously with data. Or you can trigger the timing circuit externally—either by supplying a pulsing voltage of only +10v into 20K ohms impedance, or simply by causing impedance to drop to 100 ohms or less through shorting-out or other means.

Thus your "time" signal may actually be an event marker related to shaft rotation, belt movement, or any other effect which might be more conveniently fed to the timing circuit than to a galvanometer.

(Owners of Visicorders 906, 906A, and 906B will be glad to know that only a *field-change* is necessary to economically and easily add this timing system to their instruments).

Write today for full information on the brand-new 906C Visicorder. Ask for Catalog HC-906C. Or call us at SKyline 6-3681, Direct Distance Dialing Code 303.

Minneapolis-Honeywell, Heiland Division
5200 East Evans Avenue, Denver 22, Colorado

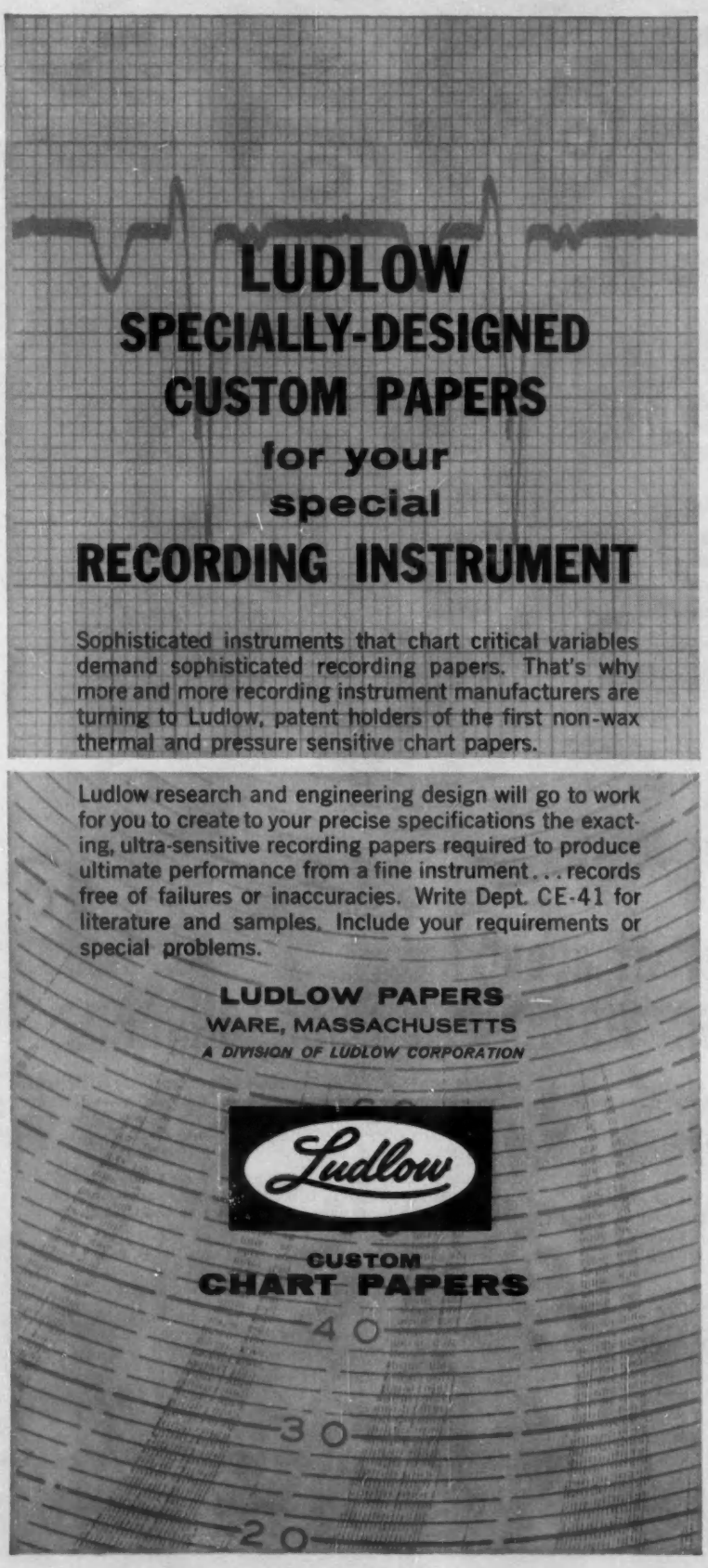
Honeywell

First in Control
SINCE 1906

HONEYWELL INTERNATIONAL

Sales and Service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

CIRCLE 237 ON READER SERVICE CARD 237



WHAT'S NEW

devices produced by the department for general industry use.

Charles E. Branscomb is now manager of IBM's Control Systems Dept., replacing Dr. Cuthbert C. Hurd, who has been appointed special assistant to the vice-president of research and engineering. Branscomb had been assistant to the president of IBM's General Products Div.

Raymond Hamada has joined Houston Fearless Corp., Beverly Hills, Calif., as senior vice-president for operations. Hamada had been vice-president of Telecomputing Corp. and head of its Whitaker Controls Div.

Horace S. Daley is now manager of the Numerical Control Dept. of Diehl Manufacturing Co., Somerville, N. J. Daley had been a project engineer in the research and development department of Walter Kidde & Co.

R. B. Nottingham has become director of engineering at The Hoover Co.'s Electronics Div. in Timonium, Md. Nottingham has 20 years' experience in military and commercial engineering and technical management. He comes to Hoover from North Electric Co.

Maj. Gen. John A. Barclay (U.S.A., Ret.), who retired recently as the Army's second in command for missile work, has joined The Lionel Corp. as vice-president for research and development. His most recent post was as deputy commander, U.S. Army Ordnance Missile Command at Redstone Arsenal.

Benjamin Topas has joined International Rectifier Corp., El Segundo, Calif., to head company studies in surface passivation of semiconductor materials. The Czech-educated Polish chemical engineer was formerly with the laboratories of Merck & Co.

Pat Minervini has been promoted to engineering manager of the Military Electronics Div. of Daystrom, Inc., Archbald, Pa. He succeeds Edgar G. Grant, recently appointed to the new post of director of new product planning. To fill the post left vacant by Minervini—chief product engineer—Daystrom named **Bernard Plevyak.**

William F. Gingras is the new director of engineering for Jonker Business Machines, Inc., Gaithersburg, Md. Gingras was with National Scientific Laboratories, Inc., for 10 years.

CATALOGS AND BULLETINS

The first two items are examples of especially useful applications literature. Both are available by circling the indicated numbers on the reader service card, as are the other new literature items.

High vacuum pumps

This well illustrated 54-page publication serves as a miniature text on high vacuum technology as well as covering the characteristics of the manufacturer's line of equipment for producing high vacuum. After an introduction to the subject, the bulletin (numbered 6-1) goes into considerable detail in outlining the calculations used in selecting a vacuum pump; a table of condensed data on the manufacturer's vapor pumps is included. Units in the lines of metal oil, metal mercury, glass oil, and glass metal pumps are described in text, photographs, dimensions drawings and tables, and performance curves.—Consolidated Vacuum Corp., Sub. of Consolidated Electrodynamics Corp./ Bell & Howell Co. **Circle No. 400.**

Furnace controls

Both hydraulic and electrohydraulic systems for controlling industrial heating furnaces are treated in Folio 122, a 24-page catalog now available. Open hearth furnace, glass tank, reheating and annealing furnace, and soaking pit installations are covered. Photographs and two-color drawings and flow diagrams describe control of furnace pressure, heat input, fuel-air ratio, and temperature and control subsystems for automatic reversal of regenerative fuels and for two or more fuels.—GPE Controls, Inc. **Circle No. 401.**

TEMPERATURE REGULATORS. OPW-Jordan Corp. Catalog TCV-1, 8 pp. Illustrated publication gives complete engineering information and technical data on the manufacturer's line of sliding gate temperature regulators. Cutaway and dimension drawings describe the self or pilot-operated models available in sizes from ¼ through 6 in. A flow curve, sizing charts and instructions, and a price list are also included. **Circle No. 402.**

REGULATED POWER SUPPLIES. Harrison Laboratories, Inc. Long form catalog, 44 pp. Covers manufacturer's complete line of regulated power supplies. A handy check form lists each model and its latest features. Two pages are devoted to each unit, including photographs, performance curves, full description, and technical specifications. **Circle No. 403.**

LOGIC MODULES. Computer Techniques, Inc. Catalog, 16 pp. Contains detailed information for using digital logic modules in such applications as shift registers, accumulators, and counters. Dimension drawings for the modules are given, and block diagrams and schematics are included. **Circle No. 404.**

SCIENTIFIC AND TESTING INSTRUMENTS. Minneapolis-Honeywell Regulator Co., Industrial Div. Catalog G-10b, 48 pp. This condensed, revised publication covers a broad area of the manufacturer's equipment for scientific

SHOWN ACTUAL SIZE



SIZE 5 COMPONENTS

FOR SERVO SYSTEM MINIATURIZATION

A complete family of Size 5 components for every servo system function is now available from Kearfott. Stainless steel housings, shafts and bearings protect the units against environmental extremes and contribute to stability under shock, vibration, and temperature fluctuations. • Standard 26-v, 400-cps excitation. • Operating temperature range −55° to +125°C.

CHARACTERISTICS

SYNCHROS

	VOLTAGE (400 cps)	T.R.	NULL (mv)	ERROR (min)
Transmitter CJO 0565 100	26	.454	34	10
Control Transformer				
Low Z-CJO 0555 100	11.8	1.765	34	10
High Z-CJO 0552 900	11.8	1.765	34	10
Differential CJO 0595 100	11.8	1.154	34	10
Resolver				
Low Z-CJO 0585 100	26	1.0	34	10
High Z-CJO 0589 100	26	1.0	34	10

SERVO MOTORS

	J126-06	J126-02
No-Load Speed	9800 rpm	9800 rpm
Stall Torque	0.10 in. oz	0.10 in. oz
Rotor Moment of Inertia	0.175 gm cm²	0.175 gm cm²
Voltage φ1/φ2 (400 cps)	26/36-CT	26/26
Power Input/Phase	1.7 w	1.7 w

SYNCHRONOUS MOTOR

	CJO 0172 200
Pull-In Torque	0.06 in. oz
Pull-Out Torque	0.10 in. oz
Pull-Out Power	4 w

MOTOR GENERATORS

MOTOR.	CJ40812001	CJ00812650	CJO0813200
Voltage φ1/φ2 (400 cps)	26/36-CT	26/36-CT	26/26
Power/φ	1.5 w	1.5 w	1.5 w
No-Load Speed	8000 rpm	8000 rpm	8000 rpm
Stall Torque	0.10 in. oz	0.10 in. oz	0.10 in. oz
GENERATOR			
Voltage (400 cps)	26 v	26 v	26 v
Volts/1000 RPM	0.1 v	0.1 v	0.5 v
Null	1.3 mv	10 mv	6.7 mv

Size 5 gearheads range in reduction ratios from 20:1 to 1019:1 for servomotors and motor tachometers above. In addition to Size 5 clutches, brakes, and brake-clutches, Size 6 are available.

Write for complete data

KEARFOTT DIVISION
GENERAL PRECISION, INC.

Little Falls, New Jersey

Control and Instrumentation Engineers

A key research and development program is now underway at Atomics International to design long-life, compact, lightweight nuclear reactors that will provide auxiliary power systems for space applications. Many interesting problems exist to challenge electrical engineers who want to relate their present experience to reactor technology in any of the following areas:

FLIGHT INSTRUMENTATION DESIGN

Electrical control system design and/or aircraft or missile flight instrumentation design. Will establish flight instrumentation requirements, block diagrams for flight and test systems, preliminary specifications for each instrument or subsystem.

TELEMETRY

Responsible engineers to analyze, plan and specify the telemetry required to ascertain the performance of nuclear power plants during space tests. The individuals must have experience in missile instrumentation and telemetry of temperature, vibration, acceleration, etc. BS or MSEE preferred.

CONTROL ANALYSIS

Dynamic and control analysis including system start-up and full power operation. BS or MSEE plus familiarity with latest analog and digital techniques required.

CIRCUIT DESIGN

Electronics engineers experienced with both vacuum tube and magnetic devices to design and develop control circuits for compact nuclear power plants.

All qualified applicants will receive consideration for employment without regard to race, creed, color, or national origin.

For specific details write: Mr. C. J. Newton, Personnel Office, Atomics International, 8900 DeSoto Avenue, Canoga Park, California.

ATOMICS INTERNATIONAL
DIVISION OF NORTH AMERICAN AVIATION

NEW Stromberg-Carlson lightweight telephone handsets



. . . for a wide range of applications such as dictating systems, mobile radio, carrier and microwave.

These new lightweight Stromberg-Carlson handsets, No. 33 and No. 35, incorporate push-to-talk switches, broadening the range of their applications. Both feature high-gain, high-efficiency transmitter and receiver.

The No. 33 model is furnished with a bar-type switch, located on the underside of the handle.

The No. 35 handset is furnished with a button switch on the side of the handle near the receiver end. Also available with both button and bar switches.

For technical details and ordering information, contact any of these sales offices: Atlanta—750 Ponce de Leon Place, N.E.; Chicago—564 W. Adams Street; Kansas City (Mo.)—2017 Grand Avenue; Rochester—1040 University Ave.; San Francisco—1805 Rollins Rd.

GENERAL DYNAMICS /ELECTRONICS

CIRCLE 288 ON READER SERVICE CARD

READ YOUR OWN COPY—

AND BE ON TOP OF THE LIST FOR CONTROL ENGINEERING EVERY MONTH!



Read it while it's hot!

Why wait days or even weeks for a dog-eared pass-along copy on the office routing list? Read your own fresh-off-the-press copy . . . enjoy all the advantages of CONTROL ENGINEERING scoops and newsbreaks.

Give yourself a break!

Read CONTROL ENGINEERING when you want to, where you want to, as long as you want to. Nobody's read it before you . . . nobody's waiting to read it after you.

Keep it . . . it's all yours!

Read your own **complete** copy (no pages torn out by the reader ahead of you on the list). Save the entire issue for your files . . . or tear out the easy-to-remove perforated pages you want to keep.

ORDER YOUR OWN PERSONAL SUBSCRIPTION — NOW AT NEW, LOW RATES . . . ONLY $3 A YEAR

Page 240A

NEW SUBSCRIPTION APPLICATION CARD

(Subscriptions solicited only from engineers and technical management men)

Yes! I want my own personal copy of CONTROL ENGINEERING every month. Enter my subscription at the new, low price of only $3* for one year. Check here ☐ for 3 years at $5*

(*United States and Canada only. Overseas rates on request.)

☐ Payment enclosed ☐ Bill me ☐ Bill company

ON-

M-

Name _____ Position _____

Home Address _____

City _____ Zone _____ State _____

Company Name _____

Product Manufactured or Service Performed by Company _____

Please indicate business location

Street _____ City _____ Zone _____ State _____

☐ Check here if you want publication sent to business address

Please print — and fill out completely for best service

ON-9-61

NEW SUBSCRIPTION APPLICATION CARD

(Subscriptions solicited only from engineers and technical management men)

Yes! I want my own personal copy of CONTROL ENGINEERING every month. Enter my subscription at the new, low price of only $3* for one year. Check here ☐ for 3 years at $5*

(*United States and Canada only. Overseas rates on request.)

☐ Payment enclosed ☐ Bill me ☐ Bill company

ON-

M-

Name _____ Position _____

Home Address _____

City _____ Zone _____ State _____

Company Name _____

Product Manufactured or Service Performed by Company _____

Please indicate business location

Street _____ City _____ Zone _____ State _____

☐ Check here if you want publication sent to business address

Please print — and fill out completely for best service

ON-9-61

IF YOU ARE NOT ALREADY A SUBSCRIBER . . .

there was never a better time to enter your subscription!

CONTROL ENGINEERING subscription rates have been reduced!

1 year ..... **now $3 (formerly $5)**

2 years ..... **now $4 (formerly $8)**

3 years ..... **now $5 (formerly $10)**

But only the price is changed! All of CONTROL ENGINEERING's outstanding qualities will be continued. In addition . . . editorial coverage has been expanded to include the new feature department, "Information Systems".

If you need further proof that this is a value-packed offer —

. . . leaf through this issue again and note the quality of CONTROL ENGINEERING's editorial content . . . unsurpassed anywhere in the field of technical literature.

Then use one of the cards below to order your subscription!

Page 2408

FIRST CLASS
PERMIT No. 64
NEW YORK, N. Y.

BUSINESS REPLY MAIL
No Postage Stamp Necessary if Mailed in the United States

– POSTAGE WILL BE PAID BY –
McGRAW-HILL PUBLISHING CO., Inc.

CONTROL ENGINEERING
330 WEST 42nd STREET
NEW YORK 36, N. Y.

Fill out this card and tear off along dotted line

FIRST CLASS
PERMIT No. 64
NEW YORK, N. Y.

BUSINESS REPLY MAIL
No Postage Stamp Necessary if Mailed in the United States

– POSTAGE WILL BE PAID BY –
McGRAW-HILL PUBLISHING CO., Inc.

CONTROL ENGINEERING
330 WEST 42nd STREET
NEW YORK 36, N. Y.

Pass this card along to a friend or business associate

and testing work, including recorders and indicators, magnetic tape systems, data handling equipment, and nuclear instruments. A typical product page includes a photograph, a concise technical description, primary specifications, and a reference to other technical literature. An approximate price range for each device is also included. **Circle No. 405.**

ANALYTICAL INSTRUMENTS. Philips Electronic Instruments. Catalog, 28 pp. Contains specifications and operating data on seven X-ray analytical instruments for research and production control. Described by photographs and concise description are electron probe micro-analyzers, spectographs, spectrometers, diffractometers, and cameras. In addition to these instrument lines, information is provided on accessory equipment, specimen holders, etc. **Circle No. 406.**

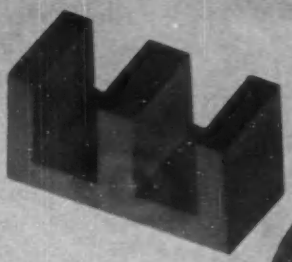
ELECTROMECHANICAL COMPONENTS. Clifton Precision Products Co., Inc. Catalog C-6-61, 42 pp. Covers manufacturer's line of electromechanical components, including synchros, resolvers, motor-generators, and miniature servo assemblies. Photographs and dimension drawings are given for each component, along with tables of specifications. An illustrated section is devoted to synchro conventions. **Circle No. 407.**

PUMP, COMPRESSOR SELECTOR. Gast Manufacturing Corp. **Slide rule.** This cardboard rule is used to select models of the manufacturer's rotary air pump by setting in the required air flow at 0 psig. The reverse side of the rule gives motor horsepower requirements and complete air flow characteristics over the range of 0 to 28 in.Hg vacuum or 0 to 30 psig pressure for each model number. **Circle No. 408.**

INDUSTRIAL RELAYS. General Electric Co. Bulletin GEA-7329, 12 pp. Describes a new 10-amp, 300-volt industrial relay designed to cut control panel space requirements. Booklet shows how the space needed is reduced by eliminating the requirement for a wiring trough. Picture-caption stories tell how the relay is designed to facilitate wiring and installation. Tables of ordering information and accessories are included, and dimensional drawings are given. **Circle No. 409.**

DIGITAL INSTRUMENTATION. Computer Measurements Co. Catalog, 20 pp. Illustrates and describes company's line of solid state and vacuum tube digital instrumentation equipment. Included are electronic counters, frequency meters, preset counter-controllers, printers, and readouts. Complete tables of specifications are given in which prices are included. **Circle No. 410.**

NUCLEAR INSTRUMENTATION. General Electric Co. Bulletin GEA-7259, 8 pp. Covers the range of nuclear instrumentation services available from this company, including design, development, manufacture, installation, maintenance, and on-site testing of systems and components. A typical reactor control system incorporating more than 20 available nuclear instruments is illustrated and described. Specialized services such as con-



SHOWN TWICE NORMAL SIZE



HIGH PERMEABILITY FERRITE

Kearfott's MN-30 ferrite is a highly machinable, high-permeability ferrite for use in magnetic cores. Its low losses and high saturation magnetization permit efficient application at frequencies up to 500 kc, while eddy current losses are minimal due to the material's high resistivity. Custom shapes and sizes available with dimensional tolerances within ± .001, density ranges from 4.9 to 5.0 gm/cm³. High quality and uniformity are assured through special compounding techniques, automatic control of firing, and rigid quality control.

TYPICAL CHARACTERISTICS

Initial Permeability at 21°C and 5 kc	3000 Min.
Maximum Permeability, measured at 2000 gauss	6000
Flux density at 7 oersteds, using Rowland Ring Test Circuit and Fluxmeter	4600 gauss
Flux Excursion for 1 oersted	3500 gauss
Retentivity (B_r)	1300 gauss
Coercivity (H_c)	0.13 oersteds
Loss Factor 1 μ Q at 50 kc	7.5×10^{-6}
Loss Factor 1 μ Q at 500 kc	30×10^{-6}
Temperature Coefficients of permeability (% per °C):	initial
From −30°C to +125°C	0.28
Curie Temperature	over 180°C
D. C. Restivity	250 ohm-cm

(All magnetic properties are held within a tolerance of ±15%)

Write for complete data

KEARFOTT DIVISION
GENERAL PRECISION, INC.

Little Falls, New Jersey

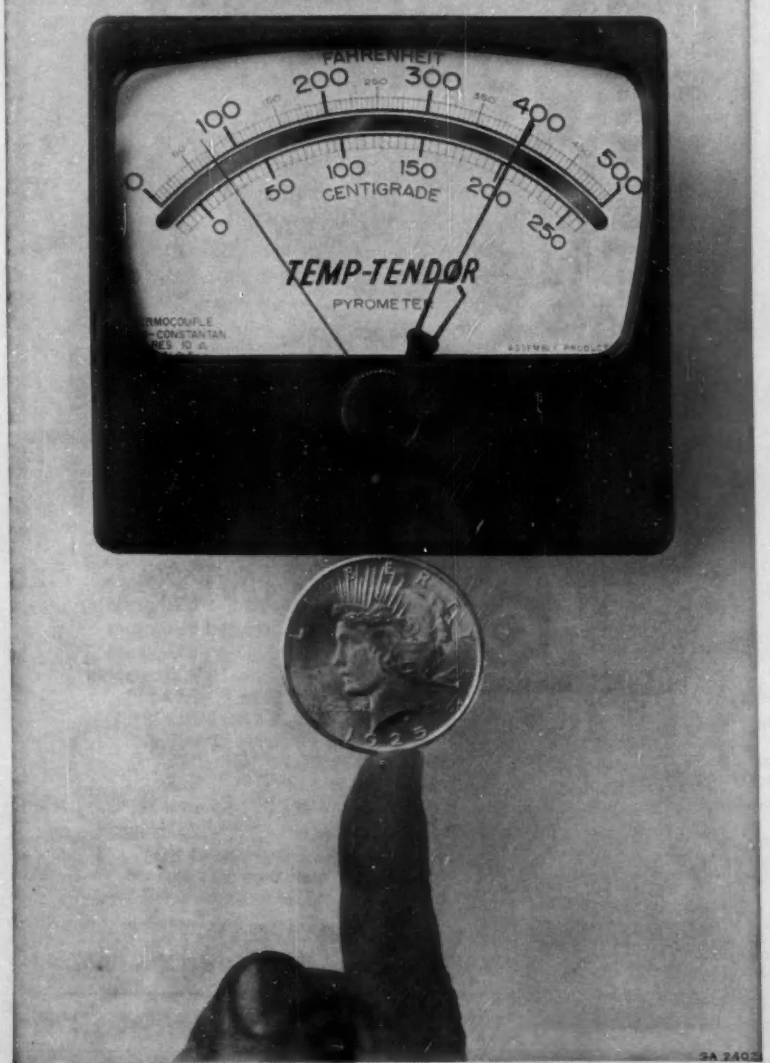
CIRCLE 241 ON READER SERVICE CARD

A NEW, SMALLER TEMP. CONTROL PRICED FOR THE OEM

Here you see, at about four-fifths actual size, A. P. I.'s new and handily compact temperature control, the Model 450 Temp-Tendor. It's a natural for "built-in" jobs. Measuring just 4" x 4¼" x 5½" overall, it's as easy to mount as a panel meter, requires no more than a meter-sized panel space. And it goes for a remarkably low OEM price. • For your money you get: a time-proportioning control capable of maintaining temperature to within ±1°F. of set-point, with built-in t/c length compensation adjustment, t/c break protection, fail-safe circuitry, instantly adjustable set-point, and a number of other features usually found only in instruments many times Temp-Tendor's modest size and cost. Available in eight standard ranges, from 0-300°F to 0-2500°F. Our Data Sheet No. 24 will give you detailed specifications. Drop us a line, and we'll put a copy in the mail.



ASSEMBLY PRODUCTS INC.
CHESTERLAND 77, OHIO



242 **CIRCLE 242 ON READER SERVICE CARD**



QuiK-Konnect PLUGS AND JACKS

New Honeywell QuiK-Konnect Plug and Jack Assemblies provide fast, foolproof connection of thermocouples to extension wire, and thermocouple extension wire to instruments. Inserts of different diameter positive and negative poles insure correct polarity every time. Inserts are easily removed for field calibration change or replacement, and can be furnished in different metals to match thermocouple alloy. Honeywell Quik-Konnect Accessories include identos, cable clamps, and tube adapters.

Get complete details from your nearby Honeywell field engineer, or write today for Specification Sheet FS 005-3. Minneapolis-Honeywell, Wayne and Windrim Avenues, Philadelphia 44, Pa. In Canada, Honeywell Controls, Ltd., Toronto 17, Ontario.

Honeywell
First in Control
SINCE 1888

CIRCLE 289 ON READER SERVICE CARD

sultation and personnel training are also detailed. **Circle No. 411.**

MEASURING INSTRUMENTS. Keithley Instruments, Inc. 1961-62 Catalog, 32 pp. Gives complete details on manufacturer's entire line of instruments including electrometers, micro-microammeters, a microvoltmeter, regulated voltage supply, and high megohm bridge. Photos, simplified schematic diagrams, and complete tabulations of technical data are given. **Circle No. 412.**

INDUSTRIAL VALVES. Hydromatics, Inc. Catalog, 16 pp. Covers complete Flo-Ball industrial valve line including several series of flanged valves, screwed end bar stock valves, and shutoff valves designed for vacuum up to pressures of 3,000 psig. Cutaway drawings, phantom and exploded views are used to describe the valve models. Charts of materials of construction, pressure-temperature curves, and dimensional information are also included. **Circle No. 413.**

METAL DETECTION. Morehouse Machine Co. Bulletin 203, 8 pp. Explains the operation of the manufacturer's Metabloc radio frequency metal detecting equipment. Covers the installation and operational factors which affect sensitivity of RF metal detecting and also stresses requirements of installation that affect satisfactory operation. Diagram of a typical metal detecting and control setup is given. **Circle No. 414.**

TEMPERATURE TRANSMITTER. The Foxboro Co. Bulletin 13-17C. Describes design features of Type 12A pneumatic temperature transmitter. Emphasized are compact construction, force-balance mechanism, and automatic compensation for ambient temperature and pressure changes. Shows how the transmitter can be installed and adjusted for a variety of applications. Also featured are detailed specifications, a table of temperature ranges, and descriptions of related accessories. **Circle No. 415.**

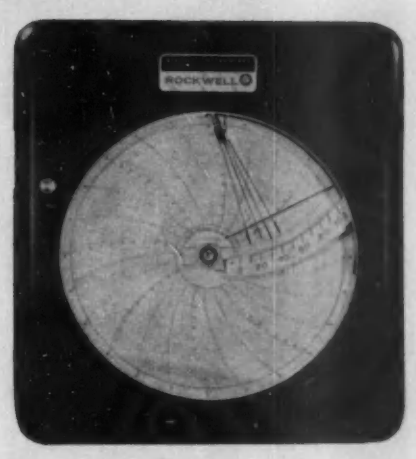
CONSTANT VOLTAGE DC SUPPLIES. Sola Electric Co. Bulletin CV-235-A, 8 pp. Revised booklet deals with areas that are of concern to users of dc power supplies. Covers theory of operation, application, available stock ratings, and features of the manufacturer's line of constant voltage units. Curves show close regulation available. **Circle No. 416.**

DISC INDICATOR. Electronics and Instrumentation Div., Baldwin-Lima-Hamilton Corp. Bulletin 4410, 6 pp. Provides detailed information on a line of disc indicators for use with resistance strain gage transducers. Includes specifications, connection details, and diagrams showing several typical system applications. Especially useful is a convenient color coded indicator selection chart. **Circle No. 417.**

SINGLE TURN POTS. Fairchild Controls Corp. Brochure, 6 pp. Describes the company's line of linear, nonlinear, and sine-cosine precision potentiometers. Performance data for 11 models of the pot line are given in easy reference tabular form. Photographs of the devices and cutaway and outline drawings are included. Special features of the line are described in detail. **Circle No. 418.**

ROCKWELL-REPUBLIC

MP-12 Analogger combines continuous integrator with 3-15 psig square root extracting receiver



Rockwell-Republic's MP-12 Analogger is a one-to-four pen, 12" circular chart pneumatic receiver recorder. It offers a 3–15 psig square root extracting receiver and a continuous integrator, making it ideal for flow measurement.

The receiver converts a 3–15 psig differential pressure signal to a linear flow record. The integrator, based on Rockwell-Republic's time-proven watt-hour meter principle, catches swings and integrates all of the flow to provide an up-to-the-moment total.

INTERCHANGEABLE PLUG-IN RECEIVERS

The MP-12 Analogger's quadrant design permits a wide variety of recording and integrating combinations to meet your exact needs. For example, up to four completely unitized plug-in receivers may be quickly and easily installed for recording process variables. Or, Rockwell-Republic continuous integrators may be employed in either or both of the upper quadrants.

LIGHTWEIGHT AND COMPACT

Every aspect of the MP-12 Analogger's design from its aluminum case to its compact (requires only 15⅜" x 17⅜" of panel area) construction makes for efficient panel utilization. All connections are at the rear of the case.

ACCURATE CALIBRATION

The MP-12 Analogger's basic receivers are factory calibrated to within ±0.5% of chart range span. All adjustment points require only a screwdriver to make receiver output settings.

For more information about the MP-12 Analogger and other Rockwell-Republic instruments and controls, just mail the coupon. RF-27

REPUBLIC INSTRUMENTS AND CONTROLS
more fine products by
ROCKWELL

Please send latest literature on the following:

☐ MP-12 Analogger ☐ Process Transmitters ☐ Controllers
☐ VRC Ratio Computer ☐ Control Stations ☐ Recorders
☐ Control Valves ☐ Drive Units ☐ V-S Gauges
☐ Desuperheating & Pressure Reducing Systems ☐ Flow Meters
☐ Electronic Control Systems ☐ Pneumatic Control Systems

Name _____ Title _____
Company _____
Address _____
City _____ Zone _____ State _____

Republic Flow Meters Co. *(Subsidiary of Rockwell Manufacturing Company)*
2240 Diversey Parkway, Chicago 47, Illinois

CIRCLE 243 ON READER SERVICE CARD

CONTROL POWER

for Air and Space

POWER
(fuel)

CONTROL
(systems)

by KIDDE

Chemical → Mono- and Bi-Propellant and Solid

Liquid → Liquefiable Gases

Gas → Nitrogen, Hydrogen, Oxygen, and Helium

Booster Attitude → Reaction Jet and Vane Actuating Systems

Satellite Orientation and Rendezvous → Reaction Jet System

Vernier Acceleration and Retro-Thrust → Proportional Thrust Motors

Aerodynamic → Vane and Jetevators

Thrust Vectoring → Nozzle Gimballing and Secondary Injection

Thrust Ranges → 0.01 lbs. to 600 lbs.

Temperature Ranges (Fluid) → −65° to +6000°F.

Response Ranges → 4 mil-seconds to 90 mil-seconds

Total Impulse → 10 lb./sec. to 100,000 lb./sec.

Pressure Ranges → 2 psi to 7500 psi

Duration and Environmental Temperature (Atmosphere-Space) → −80° to +1500°F.; 15 hours

Accurate control power is vital to the successful operation of today's...and tomorrow's...aero-space vehicles. Kidde's experience in the development of dependable, proven-in-flight missile control power systems can save you research time and money. For more information write Kidde today.

Kidde

Kidde Aero-Space Division

Walter Kidde & Company, Inc., 917 Main St., Belleville 9, New Jersey

Sales-Engineering Offices: Atlanta • Boston • Dayton • Huntington (N Y) • St. Louis • San Diego • Seattle
Van Nuys (Cal) • Washington (D C) • Walter Kidde-Pacific, Van Nuys, California
Walter Kidde Company of Canada Ltd., Montreal, Toronto, Vancouver

244 CIRCLE 244 ON READER SERVICE CARD

Genisco APD* system



HERE'S THE FIRST SMALL COMPLETE DATA-ACQUISITION SYSTEM

The new low-cost Genisco APD Data Acquisition system is a complete and compact solid-state packaged system designed to meet a wide range of instrumentation requirements. You can use it to read out thermocouples, resistance thermometers, strain-gage transducers or any other DC voltage low-impedance sensors. Modular plug-in board design allows great flexibility—one chassis can provide a complete 20-channel system.

Data is sampled at 20 samples per second; repeatability is 0.1% of full scale. Output can be shown or recorded directly in engineering units with sign indication and channel identification. Readout can be converted to punch tape, magnetic tape, typewriter or other storage medium.

The new Genisco APD requires low power and is ideal for portable, laboratory, or field use. Call or write today for prices and complete details.

***Analog-to-Pulse Duration**
Patent Applied For

Genisco
INCORPORATED

2233 Federal Ave., Los Angeles 64, California

CIRCLE 290 ON READER SERVICE CARD

ABSTRACTS

Digital speed regulation

From "Speed Regulation by Digital Methods," by R. R. Potts, AIEE Paper No. CP 61-645, presented at the AIEE North Eastern District Meeting, Hartford, Conn., May 17-19, 1961.

Digital control systems enable regulation of speed to an accuracy unobtainable by other means, and are readily fitted with punched tape, card, or other automatic programs. The system described is designed around a digital error register or reversible counter receiving two digital inputs—command and feedback pulses. The error register acts like a digital integrator with a long memory and maintains a count of the difference in total number of pulses.

The command pulse source can be a crystal oscillator or motor-driven pulse tachometer delivering pulses to the error register either directly or via a binary multiplier. With a crystal oscillator source, pulse frequency is accurate and free from drift for fixed-speed controls. By replacing the fixed frequency oscillator with a variable frequency unit, controlled acceleration and speed variation are available. Inserting a binary multiplier between the tachometer or oscillator and the error register makes externally set fractions of the input frequency available.

The error register count is converted from digital to analog for control of motor speed. Motor speed feedback from a pulse tachometer is digital, and counts down the sum of command pulses held in the error register. By using additional error registers and command pulse sources, speed control sections can be cascaded. Several different speeds can be obtained simultaneously from the same pulse source (oscillator or tachometer) by setting different binary multiplier output gates. Thus, several machine or process speeds can be regulated by the same basic speed control system. Such a system lends itself readily to program control by card or tape.

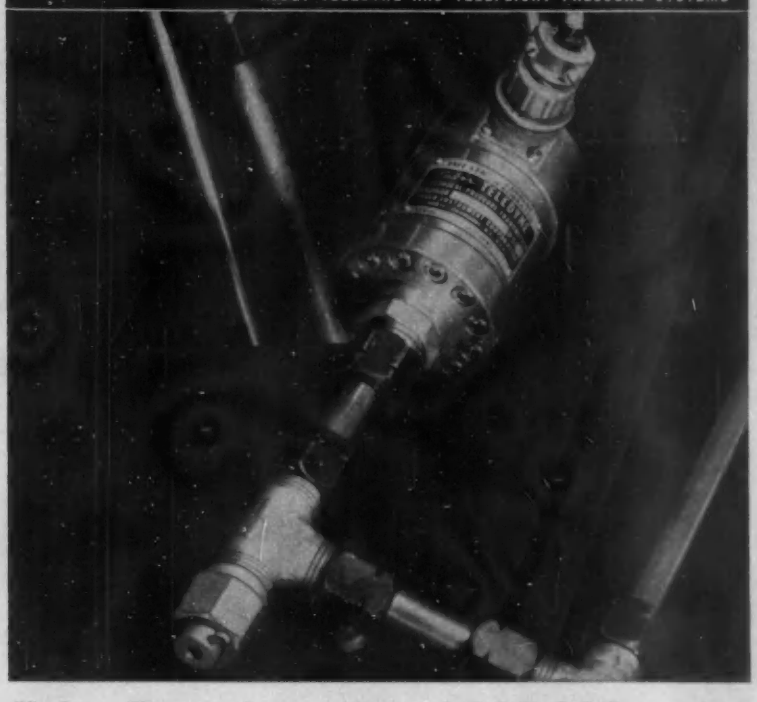
From "A Digital Speed Regulating System," by J. Dobbie and E. C. Fox, Jr., AIEE Paper No. CP 61-714, presented at the Joint Automatic Control Conference, Boulder, Colo., June 28-30, 1961.

Using a crystal oscillator to obtain a fixed pulse rate and a binary coded decimal counter to divide the pulse rate, a digital speed control system

Taber®

TELE-NEWS

ABOUT TELEDYNE AND TELEFLIGHT PRESSURE SYSTEMS



Taber Transducer logs 1,500,000 cycles in Pall filter tests without repair

The sensitivity, continuous performance and economical life of Taber bonded strain gage pressure transducers are proved in test operations at Aircraft Porous Media, Inc., a subsidiary of Pall Corporation, Glen Cove, N. Y.

This leading manufacturer of porous stainless filters uses Model 176 Taber Teledyne Pressure Transducers in fatigue testing pneumatic and hydraulic filter units for missiles, aircraft, and atomic submarines. During these tests, pressure pulses from zero to 10,000 psi are sensed and recorded on an oscilloscope at a rate in excess of 150 cycles per minute. Rate of pressure rise is in the range of 200,000 to 300,000 psi per second. The unit shown above has been in operation in excess of 1½ million cycles *without repair or overhaul.*

For full information on Taber Transducers (in pressure ranges from 0-50 to 0-10,000 psi) for test, ground support, and airborne applications, send this coupon attached to your letterhead.

TO: TABER INSTRUMENT CORPORATION
AEROSPACE ELECTRONICS DIVISION SECTION 77
107 Goundry Street, North Tonawanda, N. Y.

Send detailed information on Taber Teledyne and Teleflight bonded strain gage pressure transducers.



name _____ title _____

company _____ dept. _____

address _____

city _____ zone _____ state _____

CIRCLE 245 ON READER SERVICE CARD 245

HOW LONG IS AN INCH?

This may seem like a simple question to answer, and in some cases is answered, "It's an inch, so what" This is not true, however, for it can readily be seen that, under innumerable different environmental conditions, and under a variety of positions, an inch is as many different actual lengths as the conditions and positions to which it is subjected.

The above is only a simple illustration of how some of the problems of calibration and measurement are generated. To be sure, there are many more considerations to be investigated to get the complete answer to "How long is an inch?", but how many industries have the time, talent, or facilities to fully investigate this phenomenon?

This inch is very important, however, for it is one way by which very complex mechanisms are matched together to provide us with the means of reaching the Moon, or Venus; of finding the size of a molecule, or an atom. In the many organizations that are doing research work, that are developing systems if many kinds, that are manufacturing vehicles for the exploration of space, and by no means less important, the defending of ourselves from aggression at any point on the globe; this inch becomes the standard by which pieces are constructed, or measured, so that at some other point systems may be built which are capable of obtaining the final answer to some of those areas of effort mentioned above. If the variance between the inch at one place of research, development, or manufacture, and that of another is too great; then it is impossible to produce the finished system or answer and the effort is doomed to failure. It is vitally important, then, that even so simple a measurement as an inch be compared against a proven standard so that these variances will be held to a minimum.

The National Bureau of Standards in Washington, D. C., and in Boulder, Colorado, has the standard of length for our country. It is compared, periodically, against the International Standard in Paris, France to make certain that this measurement is the same, under given conditions and positions, the world over.

This is only one if the myriads of measurements which must be made in order to bring to dependable operation many of the systems needed to assure the success of our continuing research of space, and the means of effectively defending ourselves. It is, by far, the most simple of any of the measurements which must be made, the balance becoming increasingly complex with the more complicated systems.

General Metrics Company has been formed to provide you with calibration standards and systems designed specifically to assure you of correlation of measurement with other research, development, and manufacturing organizations; and to guarantee you direct traceability of accuracy to the National Bureau of Standards, no matter what your calibration problem may be. A good example, which might be cited here, would be that of a system capable of accurately calibrating flowmeters used to measure the flow of cryogenic fluids (Liquid Oxygen or Liquid Hydrogen). These standards and systems are all tailored to fit your specific needs and to provide a most efficient means of guaranteeing the accuracy of instruments and equipment produced or measurements made.

General Metrics Company has a staff of eminently capable men ready to assist you in the solution of any calibration problem you have. And the Company is also ready to produce and install any calibration standard or system you may need.

For details regarding our complete capabilities, simple write on your company letterhead to ***Mr. Thurlow M. Morrow, Vice President, General Metrics Company, 3142 Lincoln Avenue, Altadena, California.***

JUST OUT

ELECTROMECHANICAL COMPONENTS FOR SERVOMECHANISMS

A storehouse of practical information to help you select rotating components and use them effectively in precision servomechanisms. Discusses electrical and mechanical characteristics common to all rotating components and shows how the equivalent circuit can be used as a basic tool for understanding the system performance of a-c components. Covers a-c and d-c servomotors, tachometers, synchros, potentiometers, and other less familiar components. Gives useful data on commercial practice, applications, and other essential considerations. **By S. A. Davis,** *Electromechanical Design,* **and B. K. Ledgerwood,** *Product Engineering.* **342 pp., 315 illus. & tables, $11.50.**

10 Days' **FREE** Examination



GYROSCOPES:
THEORY AND DESIGN

Just Out. Contains up-to-date applications in instrumentation, guidance, and control. Presents a rigorous, detailed account of modern engineering practice in high-precision gyroscopics, and gives full coverage of gyrocompass, stable gyro verticals, and inertial guidance systems. Includes important design studies. **Edited by P. H. Savet, American Bosch Arma Corp. 424 pp., 215 tables & figures, $12.75.**

AN INTRODUCTION TO INFORMATION THEORY

Just Out. Explains basic concepts of probability theory and introduces information theory concepts and the fundamentals of coding theory. Provides helpful information on methods for determining channel capacity . . . Shannon's binary codes . . . and information theory in the framework of classical mathematics. **By F. Reza, Syracuse U. 500 pp., over 200 illus., $13.50.**

ENGINEERING FUNDAMENTALS for P.E. EXAMINATIONS

Just Out. Contains essential information on engineering basics needed to pass P.E. state license examinations. Polentz, Consult. Engr. 394 pp., 554 illus., $9.50. Covers mathematics, mechanics, fluid mechanics, theromodynamics, mechanics of materials, electricity and electronics, chemistry, and engineering economics. **By L. M.**

Free Examination Coupon

McGraw-Hill Book Co., Dept. CON-9
327 W. 41st St., N.Y.C. 36

Send me book(s) checked below for 10 days' examination on approval. In 10 days I will remit for book(s) I keep plus few cents for delivery costs, and return unwanted book(s) postpaid. (We pay delivery costs if you remit with this coupon—same return privilege.)

- ☐ Davis & Ledgerwood—**Electromechanical Components for Servomechanisms, $11.50**
- ☐ Savet—**Gyroscopes: Theory and Design, $12.75**
- ☐ Reza—**An Introduction to Information Theory, $13.50**
- ☐ Polentz—**Engineering Fundamentals for P.E. Examinations, $9.50**

(PRINT)

Name .....

Address .....

City .....Zone.....State.....

Company .....

Position .....

For price and terms outside U.S., write McGraw-Hill Int'l., N. Y. C. CON-9

ABSTRACTS

provides virtually drift-free speed control suitable for precision applications. Program control or decade switches set the output gates of the counter (pulse divider) to deliver the desired pulse rate to an error register (reversible decimal counter) and pulse-cancelling circuits. A pulse tachometer generates digital motor speed feedback, making the system closed-loop.

Counter output and feedback pulses are both fed to a coincidence pulse canceller, a logic circuit that sums to zero all opposite-valued pulses occurring within a set small band of time. The resulting output (if any) is sent in parallel to an error register (bi-directional counter) for loop position control, and an alternate pulse canceller for loop speed control. The counter maintains a running count of the difference between commanded and actual position of the rotating motor and furnishes the total control signal under steady state operating conditions. Counter output is decoded using weighted current summing techniques. The alternate pulse canceller logic circuits sum to zero all equal feedback and command pulse trains that are out of phase or have nonuniform spacing. Unequal pulse trains result in an output pulse train that is proportional to speed error. This output is decoded and fed to the same power amplifier as the error register output.

The digital system thus provides the functions normally expected of an analog speed control system, such as time-limit acceleration and vernier speed adjustment, and in addition provides a quality of speed regulation unobtainable from analog devices.

Pneumatic component characteristics

From "Calculation of the Behavior of Pneumatic Nozzle/Flapper Devices", by R. Winckler and K. Kramer. Regelungstechnik, December 1960, pp. 439-446. In German.

For calculating the behavior of pneumatic nozzle flapper components for transmitters and positioners, approximate values are given for pneumatic transmitters, controllers, positioners, for the relationship between air pressure and the position of the flapper, and for the forces acting upon the flapper. Finally, the method of calculation is applied to the design of a pneumatic amplifier.

CIRCLE 247 ON READER SERVICE CARD →

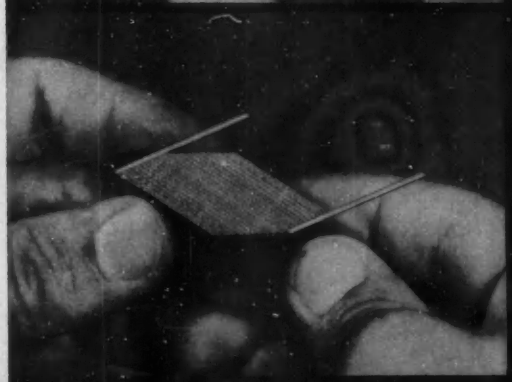
NEW WOVEN TEMPERATURE DETECTOR-GREATER ACCURACY AT LOWER PRICE!



Just peel off and stick on.



Form to fit curved surfaces.



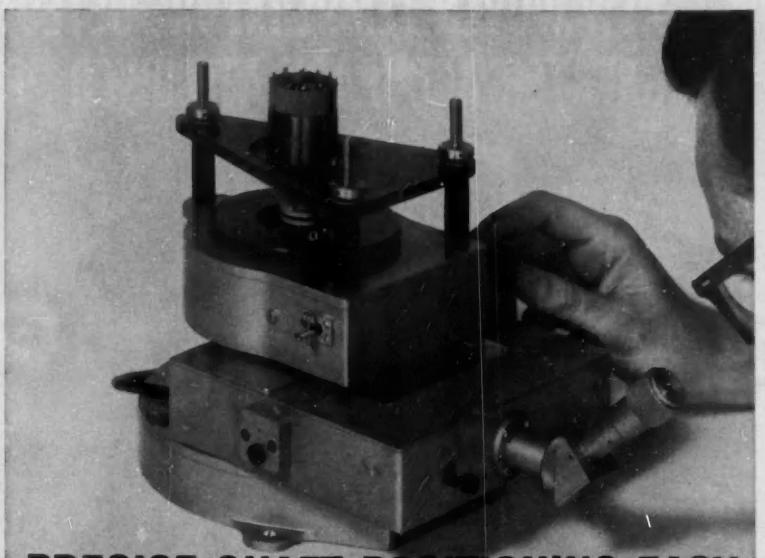
Complete accuracy on irregular areas.

The new CIC Temperature Detector combines ruggedness and increased temperature ranges (up to 1000 degrees Fahrenheit) to give you a whole new parameter in the measurement of temperature by resistance change. Its unique design of nickel or platinum resistance wire woven through fiber glass carrying threads assures sharp and accurate response — higher resistance per linear inch — calibration within ½% — and complete freedom from strain gauge effect.

Best of all the price is one third to one half that of ordinary Temperature Detectors. **You have to see it to believe it!** Just drop us a line for complete information. Evaluation prototypes immediately available.

CONTROL INDICATING CORPORATION
AN AFFILIATE OF HI-G INC.
BRADLEY FIELD, WINDSOR LOCKS, CONN.

CIC



PRECISE SHAFT POSITIONING EASY

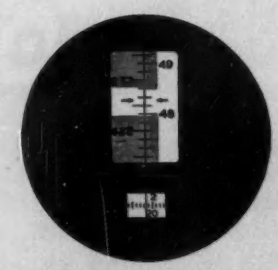
WITH GURLEY RESOLVER TEST STAND

The new Gurley Resolver Test Stand solves the long-standing need for a reliable instrument in production tests of resolvers, synchros, potentiometers and other such equipment.

The Gurley Model 7530 test stand is a precision shaft-positioning device, consisting of an optical coincidence reading system with ± 2 second accuracy, a rack and gear for precise shaft positioning, and an adaptor plate and coupling.

In use, the unit under test is mounted on the adaptor plate and is connected to the shaft of the test stand by a miniature flexible coupling. The shaft system is then quickly adjusted to an approximate angular position by means of the rapid drive disc. Accurate final positioning is accomplished with a slow motion drive. The angular position of the shaft is read directly to the nearest second of arc.

For an illustrated bulletin, write on your letterhead to Industrial Division, W. & L. E. Gurley, 537 Fulton Street, Troy, N. Y.



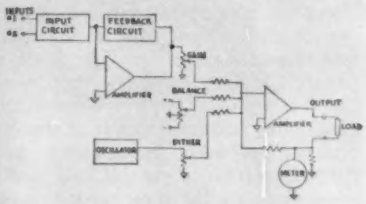
W. & L. E. GURLEY

TROY, N. Y.

248 CIRCLE 248 ON READER SERVICE CARD



AMPLIFIER FOR SERVO VALVES MODEL T5



Designed for Servo Engineers

FEATURES:

1) No B+ on Servo valve coils.
2) No interaction between gain, balance and dither controls.
3) Current feedback provides gain independent of load and virtually infinite output impedance.
4) First stage is a chopper stabilized dc amplifier which can be used as an operational amplifier.
5) Portable or rack mounting.

THOMPSON CONTROLS, INC.

209 South 18th Street

BIRMINGHAM 3, ALABAMA

CIRCLE 291 ON READER SERVICE CARD

NEW BOOKS

NEW BOOKS

New instrumentation handbook

HANDBOOK FOR INSTRUMENTATION AND CONTROL. *Howard P. Kallen, 692 pp. Published by McGraw-Hill Book Co., Inc., New York. $15.*

The reader who looks in this handbook for information on electronic or pneumatic controllers will be disappointed, and there are other surprising omissions. For example, there is a detailed section on final control elements but nothing on metering pumps, even though pH measurements, which frequently tie in with metering pumps, are treated extensively in another section. Little or nothing is said about electric differential pressure cells, electrohydraulic valve actuators, electropneumatic relays, or hydraulic control.

Despite these shortcomings, the user will have at his fingertips nearly 700 pages of valuable information which he would otherwise have to locate in scattered publications. This handbook avoids the depth of Considine's *Process Instruments and Controls Handbook* (McGraw-Hill Book Co., Inc., 1957) and directs itself to the mechanical services in power plants, heating systems, and such. It does not cover the process industries and is a practical manual, while Considine's is an engineering handbook.

An introduction to control fundamentals includes an abstracted version of the ASME Automatic Control Terminology. Pressure and draft, temperature, liquid level, and pH and conductivity measurements are covered in separate sections. Numerous diagrams, charts, and tables supply data for orifice plate calculations, control valve sizing, etc., and the ISA specification sheets for different measuring instruments are reproduced.

About half the book is devoted to systems rather than components. Boder Instrumentation and Control Systems is the largest section and covers the most modern installations. It can be argued whether a detailed discussion of chlorinators should be included in such a text, since they represent a control system in themselves; Kallen chose to omit them. Steam-pressure reducing and desuperheating are well covered in a section contributed by Republic Flow Meters Co. After describing turbine and diesel engine governing. the handbook gives good coverage of the control of heating and air conditioning systems.

Werner G. Holzbock
Birmingham, Mich.



New AGASTAT solid state time/delay/relays offer you greater reliability, wider timing ranges, and more design flexibility than has ever been available before in solid state relays. The unique "modular sandwich" construction simplifies production, speeds delivery of custom-made units.

Modular design makes possible the dependability of standardized circuit elements. Highest grade matched semiconductor components form the basis for reliability in these pre-assembled, pre-tested modules.

Choose from six basic circuit options for the range and operating type you need . . . 0.01 sec. to 10-hour delays, on *pull-in or drop-out*. All units are only 1⅛-in. sq. at base, weigh 3 to 5 oz., operate from 18 to 32 vdc, and handle loads up to 5 amperes. They are unaffected by polarity reversals, immune to voltage variations and transient spikes. Available with plug-in or solder lug terminals.

The solid state AGASTAT relay is a product of over 30 years' time delay relay experience, your assurance of performance to match the promise. For full technical information or applications assistance write Dept. 55-39.

AGASTAT TIMING INSTRUMENTS
ELASTIC STOP NUT CORPORATION OF AMERICA
ELIZABETH DIVISION ■ ELIZABETH, NEW JERSEY

IN CANADA: ESNA CANADA, LTD., 12 GOWER ST., TORONTO 16, ONTARIO, CANADA

CIRCLE 249 ON READER SERVICE CARD 249

FACT

Flexible Automatic Circuit Tester

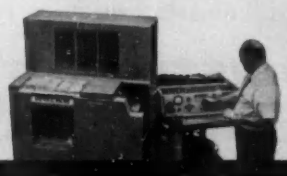
Cut programming time for circuit tests

Hughes has developed a general purpose, high-capacity test unit that dramatically cuts the time and money involved in circuit continuity and high potential testing. □ Called **FACT** (Flexible Automatic Circuit Tester), this unit uses standard IBM systems. This feature makes programming easier. And when the units to be tested have been built with IBM wiring lists, the entire test procedure can be automated. □ With **FACT** you eliminate the costs of developing special purpose test equipment. You can program complete and varied tests on an unlimited number of circuits. You can cut trouble-shooting time. And, since **FACT** is self-calibrating and self-testing, you can substantially increase the confidence level of the circuit test. □ **FACT** is production proven and available today. With three different **FACT** models (2 card programmed and 1 tape programmed) Hughes can meet every circuit testing problem. Inquire today. Write to L. W. Risner, Hughes El Segundo, L.A. 45, California. Or, better yet, call him at ORegon 8-0361, Ext. 1652.

Creating a new world with Electronics

HUGHES

HUGHES AIRCRAFT COMPANY



250 CIRCLE 250 ON READER SERVICE CARD

NEW BOOKS

Analyzing nonlinear systems

NON-LINEAR CONTROL SYSTEMS ANALYSIS. *John C. West, 223 pp. Published by the D. Van Nostrand Co., Inc., Princeton, N.J.* $5.75.

This is a succinct and competent study of a topic of great current interest, the analysis of nonlinear control systems. The first three chapters acquaint the reader with the basic concepts of nonlinearity, demonstrate the use of negative feedback in minimizing the effects of a nonlinear characteristic on a control system, and provide a brief review of linear circuit analysis, including statistical methods.

The next four chapters deal with the phase plane and its use in determining transient response of nonlinear control systems. Starting with a simple linear system, the author gradually introduces more complicated configurations, such as on-off controllers, on-off control systems with velocity feedback, and systems with saturation, all of which are amenable to analysis by phase-plane methods. The author also uses the phase-plane to examine the effects of nonlinear elements that are deliberately introduced to improve the transient performance of torque-limited systems.

Four more chapters are devoted to the use of the describing function method for evaluating the sinusoidal steady state response of nonlinear systems. Stability criteria, "jump" resonance, and subharmonic generation are the most significant topics discussed. The dual-input describing function, devised by the author, appears here for the first time in any book, and is of special interest. It offers the analyst considerably more information than the conventional describing functions since it includes the effects of harmonics. Consequently, it provides a means for determining the existence of subharmonics. This is one of the few methods that can be used to analyze systems with two nonlinearities.

The last three chapters examine the statistical approach to nonlinear system analysis and include topics such as the effect of nonlinearity on an amplitude probability distribution, the equivalent gain of a nonlinear element subjected to inputs having a gaussian amplitude distribution, and the analysis of spectral distortion caused by nonlinearities in the control system.

This book is highly recommended.

Leslie R. Axelrod
The Powers Regulator Co.

At Last...
A CAPACITANCE PROBE LEVEL CONTROLLER COMBINING:
• Amazing Stability
• High Sensitivity
THE NEW Fielden TEKTOR®



World's Most Advanced Level Controller

Others think of long term drift in terms of hours... the new Fielden TEKTOR, after months or even years of service, holds drift to 2$\mu\mu$f maximum. Revolutionary in design and construction, the new Fielden TEKTOR offers a combination of advanced features never before available in a capacitance probe instrument.

Send today for illustrated brochure with full specifications.

BUYERS BEWARE OF MISREPRESENTATION

Do not be misled by company or independent sales representatives who may be selling level equipment under the guise that it is made by Fielden. The New TEKTOR®, TELSTOR® and PNEUTRONIC® level instruments, incorporating advanced design features, can ONLY be obtained from FIELDEN ELECTRONICS, INC., HUNTINGTON, LONG ISLAND, NEW YORK or through our representatives carrying authorized credentials.

Write or call for the name of your authorized representative.

Fielden
ELECTRONICS, INC.
HUNTINGTON, NEW YORK
Telephone: (516) MYrtle 2-6045

CIRCLE 292 ON READER SERVICE CARD

SILICONTROL®



THE ONLY COMPLETE PHASE SHIFT CONTROL PACKAGE FOR SILICON CONTROLLED RECTIFIERS

(SOLID STATE THYRATRONS)

THE ALL-IN-ONE PACKAGE CONTROL FOR THE SYSTEM DESIGNER

CHECK THESE IMPORTANT ADVANTAGES . . .

1. One Silicontrol fires one or two silicon controlled rectifiers in back-to-back arrangement or bridge circuit. No added circuitry needed.
2. Eliminates *matching* of silicon controlled rectifiers. No need to select similar impedance values. Fires any two SCRs of any rating or manufacture.
3. Failsafe feature *built-in*. Prevents destruction of SCRs and load components through a wide range of overload conditions. Linear control from zero to maximum output. Can shift gate pulse more than 180°.
4. No bias needed; loss of control signal turns off unit.
5. Immune to voltage transients on supply bus resulting from adjacent switching or relay operations. Prevents SCR pulses from interfering with other circuits.
6. The *only unit* providing *all* of the above features.
7. SILICONTROLS are available from stock.
8. Both 60 cps and 400 cps models available.
9. Military packaging as required.

Send for Engineering Bulletin No. 2000

★ ★ ★ ★ ★ ★ ★ ★

VecTroL®

ENGINEERING, INC.

A Subsidiary of Sprague Electric Company

91 MAGEE AVE., STAMFORD, CONN.

CIRCLE 293 ON READER SERVICE CARD



NEW... DETAILED DATA ON SERVO MOTORS

Here's information you can use to increase speed and accuracy in high precision control and measuring equipment . . . 4 fact-filled pages on Holtzer Cabot's line of R-24 Servo Motors.

Contains 3 sets of speed-torque, performance curves: (1) For four different stator stackings with 115V on both windings. (2) For four different stackings with 115V on fixed winding and 200V on control winding. (3) For 0.7″ of stator stacking with 115V on fixed winding and 200V, 100, and 50 on control winding. Gives additional data such as starting voltage, stall torque, rotor inertia, acceleration at stall, etc.

The R-24 Line has stator cores of 2.4″ diam., available with stacking lengths of 0.5″, 0.7″, 1.0″ and 1.4″. Models with or without gear trains. Send for your free copy of Bulletin MO-3.7A. Write: Holtzer-Cabot Motor Division, 125 Amory Street, Boston 19, Massachusetts.

HOLTZER NP CABOT

MOTOR DIVISION

National Pneumatic Co., Inc., Boston 19, Mass.

CIRCLE 251 ON READER SERVICE CARD

NEW DAVEN TRANSISTORIZED CONVERTERS



REPLACE DYNAMOTORS!

- Virtually no maintenance
- Half the dynamotor's weight
- No brush replacement
- DC to DC and DC to AC models

Write today for complete information

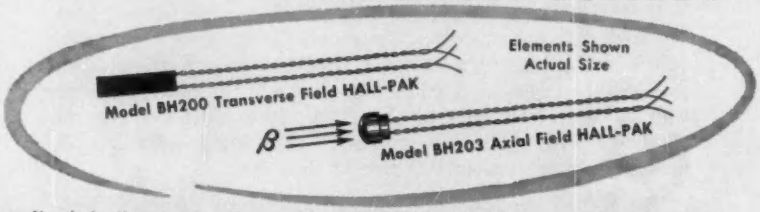
THE DAVEN CO.
LIVINGSTON, NEW JERSEY

Today, More Than Ever, The Daven ◎ Stands For Dependability

CIRCLE 294 ON READER SERVICE CARD

Performance Unparalleled! Applications Unlimited!

new BELL HALL-PAK Hall effect devices



- Non-inductive construction, making possible new and improved AC applications
- Low noise output — improved low level performance
- High Hall output combined with low zero field output voltage; eliminates need for external null voltage compensation in many applications
- Operating Temperature Range: —40°C to +85°C

New magnetic sensing devices with high performance standards never before attainable commercially. Many applications in measurement and control of magnetic fields (gaussmeters; magnetometers; production testing; AC or DC fields; magnetic tape, ink and film) wherever a magnetic transducer or Hall multiplier is needed.

Write for details.

ELECTRONIC DESIGN DEVELOPMENT • MANUFACTURING

BELL INC.
1356 NORTON AVE.
COLUMBUS 12, OHIO
PHONE AX 4-4906



Bistable Amplifier for static relay control



Richard B. Doorley, Mgr., New Products Div. Railway Maintenance Corp., Pittsburgh, Pa.

"Norbatrol helped us cut R&D time by 1 year with this Bistable Amplifier"

"Norbatrol's Bistable Amplifiers solved many control problems in redesigning our McWilliams Jack-and-Production Tamper from manual to reliable, automatic operation. Now this RMC railroad surface machine operates electronically—improves grade and cross level to accuracies never previously accomplished. And we got a bonus," Mr. Doorley continues, "these rugged, reliable static relays cost less than alternate systems."

You, too, can speed development and production time with the ultrasensitive Bistable Amplifier—it replaces mechanical relays in critical control and regulating applications. The Bistable incorporates silicon controlled rectifiers, magnetic amplifiers and attendant circuitry to give multiple inputs as low as 5×10^{-8} watts, fast response, high gain and a current output of 1 Amp at an 85° C. ambient.

GET THE FACTS on design and application data—write for technical bulletin CS60.



NE-1

NORBATROL Electronics Corp.
DEPT. A 356 Collins Avenue
Pittsburgh 6, Pennsylvania

CIRCLE 295 ON READER SERVICE CARD

FEEDBACK

(Continued from page 16)
neither the gimbal nor the gimbal bearings transmit these loads and hence neither deformation of the gimbal nor acceleration-produced error torques can result from this source.

In amplifying the author's remarks about the comparative balancing requirements of the two types of gyros, it can be stated that a two-gyro platform requires a total of six precise balance adjustments (three for each gyro), whereas a three-gyro platform requires a total of nine adjustments: six precise balance adjustments and three semi-precise balance adjustments (one semi-precise and two precise adjustments for each gyro).

H. F. Erdley
Vice President and
Director of Engineering
Guidance and Control Systems Div.
Litton Systems, Inc.

Author replies

To the Editor—

I would like to thank Mr. Erdley for his comments. Essentially, he makes three points, which I will answer in order. First, he says that "the two-gyro platform has the smaller azimuth drift rate . . . for both vertical and horizontal accelerations . . ." rather than only under vertical accelerations, as I claimed. Now, while I did neglect the averaging effect of the minor azimuth errors in a two-gyro platform, as Mr. Erdley points out, this still does not justify his statement, as will be shown by the following discussion.

Referring to the chart in Figure 2B-2 (single degree of freedom azimuth gyro), we can see that a horizontal acceleration along the A axis creates a minor drift (100 percent) around the azimuth axis y, while a horizontal acceleration along *B* does not produce any drift at all. In most three-gyro platforms, however, the azimuth gyro is mounted in such a way that its x and y axes are turned 45 deg with respect to the coordinate system of the two vertical gyros (see three-gyro platform, Figure 4). Now, looking at the azimuth chart of Figure 4, one finds that an acceleration along A causes only 70 percent of the gyro drift which the same acceleration along A would cause in case 2B-2. An acceleration along *B* in the three-gyro platform also causes a gyro drift of 70 percent, whereas the same acceleration along *B* in 2B-2 would cause no drift. This means that the displacement of the azimuth gyro



here — at last
is real stability!

0.01% total — from this new transistorized power supply

Add up *all* the factors: line and load regulation of 0.0005%; short-term drift of 0.001%; and, hum and noise of 50uv rms. Result: total stability of 0.01%!

Krohn-Hite's new Model UHR-T361 transistorized power supply is an important new bench supply for development, measurement and research. Its phenomenal stability also makes it ideal for component tests, and powering computer circuits.

Voltage range: 0-36 volts. Current: 0-1 ampere. AC output impedance: 250 microhms. Transient response: 25 usec. Line voltage: 115/230; 50-400 cps.

The extremely tight line and load regulation of the Model UHR-T361, plus its remote sensing feature, permit remote operation with better regulation at 100 feet, 0.001%, than most other supplies at their terminals. The supply also features remote voltage control for automatic programming.

Constant voltage or constant current can be obtained from this supply. The voltage is constant under pulsed or steady-state resistive or reactive loads. The current is constant to within 0.01%.

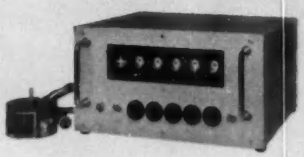
Krohn-Hite's new UHR-T361 is convection-cooled, and fully protected against short-circuit, overvoltage, overtemperature, and on/off voltage surges.

Get full information on the UHR-T361, and the 3, 5, and 10 amp Krohn-Hite transistorized power supplies.

KROHN-HITE CORPORATION
580 Massachusetts Avenue • Cambridge 39, Mass.
Pioneering in Quality Electronic Instruments

CIRCLE 253 ON READER SERVICE CARD 253

BI-DIRECTIONAL COUNTER



NEWEST IN NEW LINE OF ANALOG TO DIGITAL CONVERSION PRODUCTS FROM HYDRO-AIRE

This highly versatile, 45,000-count-per-second readout device indicates true position while going through zero in either direction. No need for external reset to establish reference, thus reducing the cost and complexity of related devices while simplifying system design and maximizing reliability. Modular construction of this compact, fully transistorized counter includes self-contained power supply and output connector.

When used with Hydro-Aire's Phototron transducer, this new counter converts inputs to Nixie tube visual readout and to digital type electrical readout for information storage, automatic machine control and process control systems — wherever precision numerical readout is required.

Detailed specifications on this and related products now available from Hydro-Aire are yours on request.

HYDRO-AIRE
DIVISION OF
CRANE

3000 WINONA AVE., BURBANK, CALIF.
Solid-state devices include time delay devices, voltage regulators, power supplies, inverters.

FEEDBACK

in the three-gyro platform of 45 deg (or better, 135 deg) averages the magnitude of the minor azimuth drift rate down to a total of 70 percent. Hence, under a horizontal acceleration the two-gyro platform has a drift rate equivalent to, not smaller than, the three-gyro type.

Along the same line, Mr. Erdley's comment that two error torques (in Figure 4) acting on the same gyro add statistically to the equivalent of one minor azimuth drift is not pertinent. Actually, as the chart shows, three torques act under the influence of a horizontal acceleration along *A* or *B*. Two of them act against the bearings of the precession axis, and only the third one, in each case, creates the 70 percent azimuth drift that is mentioned above.

Concerning the play in the bearings and the deformation of the extra gimbal in the two degree of freedom gyro, I am aware of the fact that a fully floated gyro and its gimbal theoretically show no errors under acceleration. But this assumes that balancing, flotation, and the geometry of the parts are all perfect, and remain so from run to run. This is not likely; hence we must consider the extra gimbal as an additional error source in the two degree of freedom gyro.

Mr. Erdley's last remark concerns the balancing requirements of the two types of gyros. He refers to three balancing adjustments for a single degree of freedom gyro (two precise and one semi-precise adjustment for each gyro). This is not quite correct, as indicated by the fact that there are adjustment weights provided for balancing in two directions only (or around the precession axis). Balancing in the third direction is a simple operation done during the manufacturing process and not repeated after assembly of the gyro.

Concerning the balancing adjustments of the two degree of freedom gyro, it is commonly accepted that the extra gimbal does complicate the adjustment procedure. I would like to leave in the hands of the reader the question of whether he prefers to balance three single degree of freedom gyros around one axis or to balance two two degree of freedom gyros and the additional gimbals around two axes each.

E. M. Fischel
Senior Technical Advisor
Kearfott Div.

(Continued on page 255)

A major breakthrough in temperature measurements!



THE NEW thermo-ref solid-state thermocouple reference

The new Genistron Thermo-Ref provides a constant reference temperature of 100°C., ±0.1°C., with a 10-channel uniformity of ±0.1°C. Maximum drift is less than 0.5°C. over an ambient temperature range of −55°C. to +85°C. Power consumption is a nominal of 1.0 watts over a voltage variation of 95 to 125 volts AC. These specifications and its small size and light weight make the Thermo-Ref ideal for airborne applications. Standard models are available for reference temperatures of 100°C., 121°C. and 150°C.

The Thermo-Ref measures 3⅛"x3¼"x2" and weighs approximately 12 ounces. Packaging and environmental conditions meet or exceed MIL-E-5272 and MIL-E-16400.

Write for complete technical information.

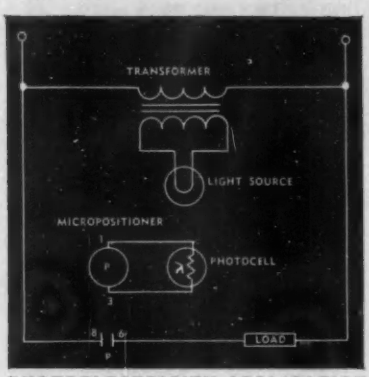
Genistron
A subsidiary of Genisco Inc.
6320 WEST ARIZONA CIRCLE
LOS ANGELES 45, CALIFORNIA

THE MARK OF QUALITY
BARBER COLMAN

Ultra-sensitive relays

HELPFUL DATA FOR YOUR CIRCUITRY IDEA FILE

The circuit drawing below indicates just one of the hundreds of ways many manufacturers utilize Micropositioner® polarized relays to solve complex control problems.



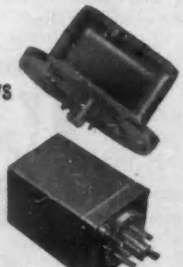
PHOTOELECTRICITY APPLICATION

Many stages of electronic amplification in photoelectric controls can be completely eliminated with a Barber-Colman Micropositioner, since a current generating photocell alone provides sufficient power to operate this relay directly.

A Micropositioner operating on 50 microwatt input (with fine silver contacts rated at 1 ampere, 110 volt 60 cycle, resistive load) *is essentially a tubeless amplifier capable of two million times amplification.*

Among the many applications for this simplified, *nonelectronic* photocell control are punch press safety controls . . . emergency lighting controls . . . door openers . . . burglar alarms . . . level controls . . . packaging, sorting, filling, and materials handling controls . . . plus many other automation functions.

If you are developing an application calling for photocell control, why not make a test with a Micropositioner designed for circuits similar to that shown above? Write for technical bulletins F7279 and F3961.



BARBER-COLMAN MICROPOSITIONER® POLARIZED D-C RELAYS

Operate on input power as low as 40 microwatts. Available in three types of adjustment: null seeking . . . magnetic latching "memory" . . . and form C break-make transfer. Also transistorized types with built-in preamplifier. Write for new quick reference file.

BARBER-COLMAN COMPANY
DEPT. U, 1848 ROCK STREET, ROCKFORD, ILLINOIS
CIRCLE 297 ON READER SERVICE CARD

FEEDBACK

Third party mediates

To the Editor—

A comparison of the merits of two-gyro and three-gyro platforms is tantamount to a comparison of the performance of double-axis and single-axis gyros. In his discussion Dr. Fischel assumes as the main source of drift rate, in either type of gyro, unpredictable mass shift, predominantly along the spin axis and to a lesser extent along transverse axes. This is a reasonable assumption for conventional gyros utilizing rotors mounted by ball bearings in floated gimbals. To the extent that it is more difficult in a complicated mechanical assembly to control mass shift along three axes than along two, a case can be made for the use of single-axis gyros. Very similar considerations hold for residual or uncorrectable anisoelasticity, which, especially in missile guidance systems, can become more significant than simple mass shift because the resulting disturbing torque can vary with the square of acceleration.

The potential performance improvement made in two-gyro platforms by taking advantage of the redundant axis in practice has not always been found to be worth the extra circuits required for the averaging function. To the writer's notion, a more significant advantage of the double-axis gyro is that it lends itself readily to case rotation as a means of compensating certain sources of error (not axial mass shift, however).

Dr. Fischel's discussion does not necessarily apply to some modern types of gyros. For example, in the case of single-axis gyros provided with gas lubricated rotor spin bearings, tests in input-axis-vertical orientation show performance so close to that in the output-axis-vertical orientation as to suggest that axial mass shift effects are not the predominant source of error. Again, consider the free-rotor type of double-axis gyro, consisting of a rotor mounted for universal freedom by means of a spherical bearing, whether with the aid of gas films or electrostatic or magnetic fields. Unpredictable mass shift of the gyroscopic element can be made strictly negligible, whereas imperfect geometry, and also certain electrical effects, can give rise to drift rates, some dependent on acceleration and some not so.

J. M. Slater
Staff Specialist
Inertial Navigation Div.
Autonetics

PHOTOTRON



FIRST IN NEW LINE OF ANALOG TO DIGITAL CONVERSION PRODUCTS FROM HYDRO-AIRE

This highly versatile basic transducer offers incremental conversion of shaft angle to digital measurement. Available in seven models, its maximum permissible speeds range from 15,000 rpm at 128 counts per revolution to 1,250 rpm at 2,048 counts, with sample rates ranging to 45,000 counts per second.

Applications for the Hydro-Aire Phototron include analog to digital shaft converters, precision analog servo with digital readout, data reduction equipment, tachometers, and precision measurement and control.

Detailed specifications are available on request. Related products soon to be available from Hydro-Aire, a member of the Crane Co. Systems and Controls Group, will include associated power supplies and binary and digital counters.

HYDRO-AIRE
DIVISION OF
CRANE
3000 WINONA AVE., BURBANK, CALIF.

CIRCLE 255 ON READER SERVICE CARD

tape to printer
card to printer
processor to printer
adc to printer
BUFFERS



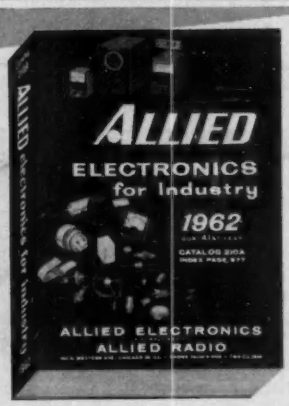
It's almost **sinfully** easy to drive rotary-bar printers when you use DI/AN's RBP Series Buffer and Control Units. All the control functions, accessory features, and format flexibility a reasonable man could want — in a surprisingly compact package. We leave room for three extra cards—for unreasonable special requirements. All solid-state, magnetic-storage circuitry with proven reliability. Price and delivery will discourage you from building your own.

We want to send you a handful of specification and applications literature on our complete line of sequential-access and special-purpose buffers. Fascinating reading. Write **today.**

di an **DI/AN CONTROLS, INC.**
944 Dorchester Avenue, Boston 25, Massachusetts • AVenue 8-7700
magnetic digital/analog systems and components

CIRCLE 298 ON READER SERVICE CARD

free send for the
ALLIED
1962 ELECTRONIC SUPPLY CATALOG
592 PAGES • MOST COMPLETE



BUY AT FACTORY PRICES
FROM THE WORLD'S LARGEST STOCKS

we specialize in the supply of:
- Semiconductors
- Capacitors
- Transformers
- Controls
- Special-Purpose Industrial Tubes
- Test Equipment and Meters
- Knight-Kit® Lab Instruments
- Knight® Paging & P.A. Systems
- Electronic Parts for Every Need
- Connectors
- Relays
- Switches
- Resistors

ANYTHING IN ELECTRONICS IN A HURRY
One order to Allied fills the whole bill—from the world's largest stocks of electronicequipment. You get same-day shipment. *You buy at factory prices.* Write today for the FREE 1962 ALLIED catalog.

ALLIED ELECTRONICS
a subsidiary of
ALLIED RADIO
100 N. Western Ave., Dept. 920-J1 Chicago 80, Ill.

ONE ORDER TO ALLIED FILLS THE WHOLE BILL
send for FREE CATALOG

CIRCLE 256 ON READER SERVICE CARD

Increased technical responsibilities in the field of range measurements have required the creation of new positions at the Lincoln Laboratory. We invite inquiries from senior members of the scientific community interested in participating with us in solving problems of the greatest urgency in the defense of the nation.

RADIO PHYSICS and ASTRONOMY

RE-ENTRY PHYSICS

PENETRATION AIDS DEVELOPMENT

TARGET IDENTIFICATION RESEARCH

SYSTEMS: Space Surveillance
Strategic Communications
Integrated Data Networks

NEW RADAR TECHNIQUES

SYSTEM ANALYSIS

COMMUNICATIONS: Techniques
Psychology
Theory

INFORMATION PROCESSING

SOLID STATE Physics, Chemistry, and Metallurgy

A more complete description of the Laboratory's work will be sent to you upon request.

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

Research and Development
LINCOLN LABORATORY
Massachusetts Institute of Technology
BOX 30
LEXINGTON 73, MASSACHUSETTS

CIRCLE 256 ON READER SERVICE CARD

MEETINGS

SEPTEMBER

Third Congress, International Association of Analog Computation, Belgrade, Yugoslavia Sept. 4-9

International Language Translation Conference, National Physical Laboratory, Teddington, Middlesex, England Sept. 5-8

International Data Processing Exhibit (in conjunction with 16th National Meeting of Association for Computing Machinery), Statler Hilton Hotel, Los Angeles, Calif. Sept. 6-8

Institute of Radio Engineers, National Symposium on Space Electronics and Telemetry, University of New Mexico, Albuquerque, N. M. Sept. 6-8

Joint Nuclear Instrumentation Symposium, sponsored by ISA, AIEE, IRE, North Carolina State College, Raleigh, N. C. Sept. 6-8

Instrument Society of America, 16th Annual Instrument-Automation Conference and Exhibit, Biltmore Hotel and Memorial Sports Arena, Los Angeles, Calif. Sept. 11-15

Third International Cybernetics Congress, Namur, Belgium Sept. 11-15

Marine Sciences Conference, sponsored by ISA and American Society of Limnology and Oceanography, Woods Hole, Mass. Sept. 11-15

Ninth Annual Joint Societies Engineering Management Conference, sponsored by ASME, AIEE, ASCE, AIIE, AIChE, AIME, IRE, Hotel Roosevelt, New York Sept. 14-15

Industrial Electronics Symposium, sponsored by IRE, AIEE, ISA, Bradford Hotel, Boston, Mass. Sept. 20-21

OCTOBER

Institute of Radio Engineers, Seventh National Communications Symposium, Utica, N. Y. Oct. 2-4

Institute of Radio Engineers, Canadian Convention, Automotive Building, Exhibition Park, Toronto, Canada Oct. 4-6

International Systems Meeting, sponsored by Systems and Procedures Association, Statler-Hilton and Pick-Carter Hotels, Cleveland, Ohio Oct. 8-11

National Electronics Conference, sponsored by IRE, AIEE, EIA, SMPTE, Hotel Sherman, Chicago, Ill. Oct. 9-11

PHAZOR PAT. PEND. NULL METER

Manufacturers of:
PHASE METERS • NULL DETECTORS • IMPEDANCE COMPARATORS • POWER OSCILLATORS • FREQUENCY STANDARDS • AUTOMATIC HI-POT •

A PHASE SENSITIVE NULL METER WHEREIN NOISE AND HARMONIC VOLTAGES ARE EFFECTIVELY ELIMINATED



MODEL 100A

PRICE $299.00 F.O.B. NEW YORK

- Allows separate balance of in-phase or quadrature in null circuits.
- Eliminates the necessity for filters.
- High sensitivity.
- Direction of null clearly shown on zero centered meter.
- Synchro zeroing without recourse to coarse and fine switching.

For further information contact your nearest representative or write for brochure

ITECO INDUSTRIAL TEST EQUIPMENT CO. 55 E. 11th ST. · NEW YORK 3 · GR. 3-4684

Other Electronic Test Equipment

Visit Booth #213, NEC SHOW, International Amphitheatre, Chicago, Oct. 9-11, 1961

CIRCLE 299 ON READER SERVICE CARD

A PRICE PLUS PRECISION BREAKTHROUGH

ON DISPLAY AT THE ISA: Booth 184



MNEMOTRON 102A record/reproduce system complete with tape transport

now — 0.2% precision in a complete, easy-to-use 2-channel analog tape system . . . only

$1,390

Now you can afford the precision data recording facilities you need . . . as few as 2 channels, as many as 4, 6, 7, on ¼" tape; and 14 on ½" tape.
Pioneered by Mnemotron's unique pulsed FM principle and fully transistorized, self-contained, interchangeable modules.
• RECORDS ALL ANALOG DATA DOWN TO-AND INCLUDING-DC IN ALL THESE INDUSTRIAL AND RESEARCH APPLICATIONS:
• Data acquisition, storage, analysis & reduction • Time scale contraction and expansion • Dynamic Simulation • Programming • Computer Read in and Read Out
• EXPANDS USEFULNESS OF PAPER RECORDERS
• Extends frequency response and channel capacity • Saves you from being "snowed" with data • Lets you look at same data at different time scales • A permanent record even if paper is damaged.
Write for complete application, price and delivery information on Mnemotron Analog Data Tape Systems and Computers for your specific needs. Systems with voice as well as data channels also available.

Features:
3 Standard Speeds: 1⅞, 3¾, 7½ ips
Frequency Response:
DC-400 cps @ 7½ ips
DC-200 cps @ 3¾ ips
DC-100 cps @ 1⅞ ips
Linearity: 0.2% full scale
Noise:
Less than —50db full scale
Crosstalk: below 70db

MNEMOTRON CORPORATION

43 South Main Street, Pearl River, New York
Pearl River 5-4015 (914)

Precision Analog Data Tape Recorders and Biological Computers

CIRCLE 257 ON READER SERVICE CARD

PINPOINT PRECISION

THROUGHOUT LARGE VOLUME



20" x 20" x 25"

LOWER GRADIENTS:
±1° C. over large portion of test volume

RANGE:
−100° F. to +600° F.

CONTROL ACCURACY:
± ¼° F.

HEATING TIME from 70°:
13 minutes to 350° F.
28 minutes to 500° F.

COOLING TIME from 70°:
6 minutes to −65° F.
9 minutes to −100° F.

Call Delta representative or write direct for specifications

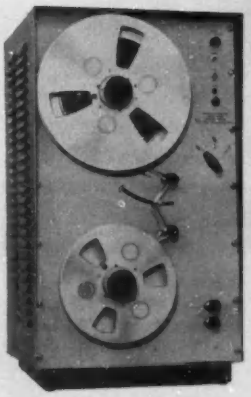
MODEL 1060B
Temperature Chamber
Cabinet Optional

DELTA DESIGN INC.

3163 ADAMS AVE. SAN DIEGO 16, CALIFORNIA
ATWATER 3-3193 • CABLE: DELTA • TWX: SD 6488-U

CIRCLE 300 ON READER SERVICE CARD

TAPE TAMER

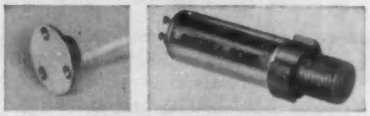


NEW EECO HIGH-SPEED MAG TAPE REWIND UNIT $690, 6 WEEKS DELIVERY

Tame your tape rewind problems at the industry's lowest cost for all these features. Fast automatic stop when tape ends or power fails. Rewinds 10½" reel in 75 seconds. Constant tension for unusually even winding. Tension selector. Universal hub accepts NAB, UNIVAC or IBM reels. Precision guides handle ½", ¾" or 1" tape without adapters. Unit takes reels up to 14" diameter. Operates on 115v ac, 60 cps, 150 va. Initial availability 6 weeks. Send for Data File TR-300.

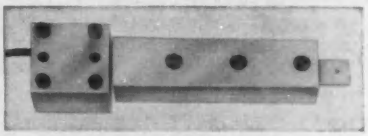
AUTOMATION DIVISION
Electronic Engineering Company *of California*
1601 E. Chestnut Ave. • Santa Ana, Calif. • KImberly 7-5501 • TWX: S ANA 5263
EE 1-54
Representative in Western Europe and Israel: Electronic Engineering S.A., C. P. 142, Fribourg, Switzerland

new SOLID STATE TRANSDUCERS

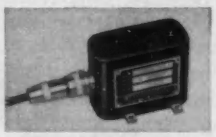


PRESSURE





LOAD



ACCELERATION

Piezoresistive semiconductor strain gages and transducers with exceptional combinations of performance characteristics . . .

- *High Output (volts)*
- *High Accuracy (0.1%)*
- *High Frequency (KC)*
- *Low Deflection*
- *Reliability*
- *Small Size*
- *AC or DC Power*
- *Static or Dynamic*

Write for further details and for information on gaging services and engineered systems.

KULITE-BYTREX CORPORATION
50 HUNT ST. • NEWTON 58, MASS.

Semiconductor Strain Gages
Semiconductor Strain Gage Devices

CIRCLE 301 ON READER SERVICE CARD



You can't see a .001"....

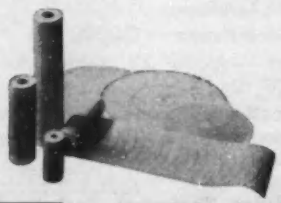
without the aid of special magnifying lenses like those used by the GC Recording Chart Inspector in the picture above.

These are the grid line calibration tolerances worked to in *all* GC recording charts to make sure the chart you buy from us will give you the *right* answer *all* the time.

Take rigid inspection standards like these and add repeated paper and ink tests, continuous humidity control in production and storage areas, and speed of printing and delivery—you'll see why more than 5,000 chart users rely regularly on GC for quality and dependability.

More than 15,000 different chart types are stocked at GC. We also design and print charts for any special purpose you may have.

Let us send you our new complete sample brochure.



GC RECORDING CHARTS

Distributed by:
TECHNICAL SALES CORPORATION
189 Van Rensselaer St., Buffalo 10, N. Y.
A Subsidiary of:
GRAPHIC CONTROLS CORPORATION
Buffalo 10, N. Y.

CIRCLE 302 ON READER SERVICE CARD

MEETINGS

OCTOBER

Forum on Legal and Practical Questions Raised by Computer Use, sponsored by American Bar Association and Joint Committee on Continuing Legal Education, American Law Institute, Pick-Congress Hotel, Chicago, Ill. Oct. 19-21

Institute of Radio Engineers, Second New York Conference of Electronic Reliability, NYU College of Engineering, University Heights, N.Y. Oct. 20

National Fluid Power Association, Fall Meeting, Sheraton Hotel, Philadelphia, Pa. Oct. 22-25

Institute of Radio Engineers, East Coast Aeronautical and Navigational Electronics Conference, Lord Baltimore Hotel, Baltimore, Md. Oct. 23-25

International Symposium on Aero-Space Nuclear Propulsion, sponsored by IRE, AEC, NASA, Hotel Riviera, Las Vegas, Nev. Oct. 24-26

1961 Computer Applications Symposium, sponsored by Armour Research Foundation, Morrison Hotel, Chicago, Ill. Oct. 25-26

Institute of Radio Engineers, 1961 Electron Devices Meeting, Sheraton Park Hotel, Washington, D. C. Oct. 26-28

NOVEMBER

Sixth Annual Special Technical Conference on Nonlinear Magnetics, sponsored by AIEE, Statler-Hilton Hotel, Los Angeles, Calif. Nov. 6-8

Seventh Annual Conference on Magnetism and Magnetic Materials, sponsored by AIEE, IRE, American Institute of Physics, American Institute of Metallurgical Engineers, Hotel Westward Ho, Phoenix, Ariz. Nov. 13-16

Electronic Systems Reliability Symposium, sponsored by Kansas City Section IRE, Linda Hall Library Auditorium, Kansas City, Mo. Nov. 14

Northeast Research and Engineering Meeting (NEREM), sponsored by IRE, Boston, Mass. Nov. 14-16

1961 Annual Display of the Aerospace Electrical Society, Pan Pacific Auditorium, Los Angeles, Calif. Nov. 15-17

1961 Electron Devices Meeting, Sponsored by IRE Professional Group on Electron Devices, Shoreham Hotel, Washington, D.C. Nov. 20-21



NEW! Heat-sensitive RECORDING CHARTS

Quality-Proven in Test after Test!

After lengthy research and extensive testing, GC brings you the best all purpose heat-sensitive oscillograph paper for a wide range of recorders and every industrial application.

GC heat-sensitive charts provide finer trace lines for accuracy in recording, outstanding dimensional stability, and greater resistance to abrasion in handling.

Through volume production, and with over 50 years of experience, the world's largest producer of recording charts can bring substantial savings to you for all your chart requirements.

Our new folder gives you the facts on GC heat-sensitive charts. Clip and mail the coupon for your copy.

GC RECORDING CHARTS

Use This Coupon
TECHNICAL SALES CORPORATION
a subsidiary of
GRAPHIC CONTROLS CORPORATION
189 Van Rensselaer St., Dept. CE
Buffalo 10, N. Y.
Please send me your new folder on GC heat-sensitive Recording Charts.
Name_____
Firm_____
Address_____
City_____ State_____

CIRCLE 259 ON READER SERVICE CARD

NOW.....

Check Out Critical Temperatures on

Microminiature circuitry
Transistors
Diodes
Breadboards
Motors
Generators
Bearings
Transformers
Packaged equipment



with

Easy-To-See **COLOR CHANGING**

Thermochrom
CRAYONS
DetectoTemp
PAINTS

Simple to apply, these indicating materials show the temperature by changing to a distinct, totally different color. They provide a most convenient means for determining whether equipment or components are operating within specified temperature ranges.



Thermochrom
18 crayons cover temperatures from 65° C to 670° C.

DETECTOTEMP
Available in 4 oz. and 1 lb. metal cans. 36 types cover temperatures from 40° C to 1350°C. Multichange paints available with as many as 4 color changes.

Write for colorful folder.

CURTISS WRIGHT
CORPORATION
Princeton Division • Princeton, New Jersey
Also available through your AIRCO distributor
In Canada: Canadian Curtiss-Wright Ltd., Industrial Process Controls, Davis Road, Oakville, Ontario

WHAT'S AVAILABLE IN REPRINTS

The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient filable form. Single copies of any reprint can be obtained at the nominal cost listed below by circling the corresponding numbers on a reader service card, p. 221. Don't send money with card, we will bill you later. For multiple copies write Reprint Dept. Quantity rates will be quoted on request.

513—Measuring With Solid State Transducers, 16 pp. Contains all articles from the Measurement section of Control Engineering's September 1961 theme issue on Solid State in Control. Covers piezoelectric and piezoresistive strain gages, Hall effect transducers, semiconductor thermometers, and a number of devices for sensing radiant energy based on various solid state phenomena. Variables that can be measured with such transducers include temperature, strain, power, current, magnetic field strength, and displacement. 50 cents.

512—Ready Reference Data Files—IV, 20 pp. Contains Data Files 37 to 48. Subjects range from information display to semiconductor voltage regulators to loaded parallel-T filters. 50 cents.

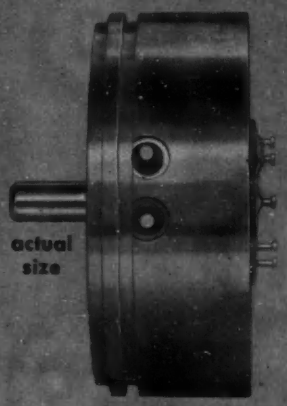
511—Industrial Process Chromatographs: What they do, How they work, Who makes them, 14 pp. Reviews basics of chromatographic techniques including latest refinements to increase sensitivity and reduce analysis time of this versatile stream analyzer, describes major components and their functions, and highlights operation and specific features of six commercially available chromatographs. 50 cents.

510—The Use of Digital Computers in Science, in Business, and in Control, 112 pp. A collection of 14 articles published over a two-year period as the Digital Applications Series. Prominent authorities cover the application, programming, overall system design, and commercial availability of digital computers in all phases of business, industry, and military. (An old reprint but with basic and practical content of value today). $3.00.

509—Applying Incremental Servos, 24 pp. Incremental servos offer many advantages in closed-loop systems. A grouping of five basic articles compares stepping and stepless control, describes the operation and analysis of solenoid-ratchet and phase-pulsed synchronous steppers, shows 16 applications of stepping motors, tabulates pertinent characteristics of available step-

(Continued on page 261)

DIGITAL SYNCHRO



Reliability — 6 years mean-time-to-failure

Highest Speed — 6 million counts per minute

Optisyn® is a unique incremental encoder . . . a direct replacement for analog servo components.

Optisyns are excellent for:

- Counting
- Numerical control
- Digital tachometers
- Shaft encoding
- Angle transmission systems

Specifications

- Reliability — 50,000 hrs. operating life or 200 million revolutions
- Low Torque — .05 in.-oz.
- Speed Range — 0-3000 rpm
- Size — Model 23, shown above, 2.3" dia.
- Broad line of models covering resolution range of 100 to 4096 counts per shaft revolution

Send for Technical Bulletin No. 611 or call Stoneham, Massachusetts, 438-3900

DRC **DYNAMICS RESEARCH CORPORATION**
38 Montvale Ave., Stoneham, Mass.

See at ISA Show Booth #116-B

CIRCLE 303 ON READER SERVICE CARD



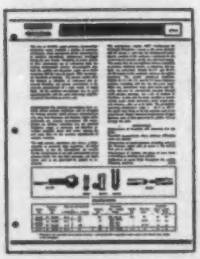
COVER WIDE FREQUENCY AND DYNAMIC RANGES

MORE THAN

10 KC AND

200 db

Massa A.D.P. (Ammonium Di-Hydrogen Phosphate) Sound Pressure Microphones provide reliable waveform reproductions of broad band sound such as generated by high intensity acoustic noise facilities. Frequency responses, which extend well into the ultrasonic range, make these instruments ideally suited for steady state high frequency work or with transients having extremely fast rise times. Compact in design, these microphones make excellent probe elements which fit into tiny circular openings and hard to reach spaces.



Each model presents near infinite acoustic impedance and makes accurate measurements over wide dynamic and frequency ranges under practically any acoustic environment. Choice of model depends on sensitivity, ultimate frequency range and available test space.

Write for Technical Bulletin SPM-5

MASSA
A DIVISION OF
COHU
ELECTRONICS, INC.
282 LINCOLN STREET
HINGHAM, MASSACHUSETTS

CIRCLE 304 ON READER SERVICE CARD

REPRINTS cont'd

ping motors, and discusses the problems of interlocking the devices. 65 cents.

508—Transistor Switches for Industrial Service, March 1961, 24 pp. Industry requires reliable, inexpensive, and fast switching devices. This special report thoroughly covers one possible solution to this requirement—transistor logic modules packaged for industrial use. Topics include how transistors perform logic functions, available systems and components, tips on selection and use, and case studies of industrial applications. 65 cents.

507—Tips on the Use of Electromechanical Relays, 24 pp. Compilation of five articles presents practical information on the design, test, and use of relay control systems. Topics covered include: testing relay electrical reliability, improving system reliability, narrowing relay differential, logical synthesis of systems, and verifying relay control circuits. 65 cents.

506—What You Should Know About Adaptive Systems, 17 pp. Is there such a thing as an adaptive control system? What approaches have been taken? What does the future hold? These are the questions the author answers in this three-article reprint, in sufficient detail and with sufficient references to provide a basic grounding in this latest area of control engineer interest. 50 cents.

505—The Basics of Optimum Response Relay Servos, 17 pp. Three part series summarizes all of the important design techniques that have been used to optimize the response of relay servos. The reprint describes the development of the optimum switching criteria, and outlines the progress that has been made in implementing this theory with hardware for second order and higher order systems. Extensive references provide a guide for further study. 50 cents.

504—System Characteristics of Modern Guidance Techniques, August 1960, 22 pp. In this special report five experts from three companies cover the system characteristics of inertial navigators, guidance radars, Doppler radar techniques, modern techniques in celestial navigation, and perceptive guidance systems. 65 cents.

503—How to Determine Stream Analyzer Dynamics, 8 pp. Package of two articles shows how analyzers can introduce dynamic errors, how to determine analyzer dynamics, and how to improve performance. The instrument used is a differential refractometer but techniques can be extrapolated to other types of analyzers. 40 cents.

502—Survey of Dynamic Display Techniques, 20 pp. The function of these newly developed techniques is to put up-to-date information in the hands of human operators of control systems when the information changes at a high rate. Both basic approaches and commercial hardware are discussed for cathode ray tube displays, optical systems, and miscellaneous devices ranging from TV pickup to matrix cells. 50 cents.

501—Six Transducers for Precision Position Measurement, May 1960, 6 pp. Explains operation and gives practical application hints for six precision position

(Continued on page 262)



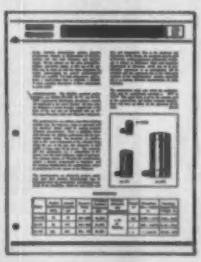
PRIMARY STANDARDS

NOW AVAILABLE FOR

ROUTINE TESTING

Primarily designed as precision standards, Massa A.D.P. (Ammonium Di-Hydrogen Phosphate) Crystal Accelerometers never need calibration. Their use in routine vibration measurements eliminates the acoustical accelerometer check prior to the actual test run. This means savings in calibration man-hours amounting to many times their purchase price. Many Massa Accelerometers have been doing this for as long as fifteen years.

Only Massa Accelerometers use the A.D.P. crystal. Precise manufacturing techniques make possible full realization of the uniformity, stability and reliability inherent in this exclusive material.



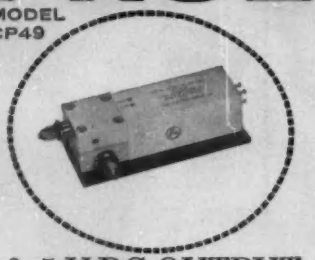
Write for Technical Bulletin, VM

MASSA
A DIVISION OF
COHU
ELECTRONICS, INC.
282 LINCOLN STREET
HINGHAM, MASSACHUSETTS

CIRCLE 261 ON READER SERVICE CARD

PACE

MODEL CP49



0-5 V DC OUTPUT
PRESSURE
TRANSDUCER
FOR OPERATION to 250°F

Ranges: 0.5 to 2,500 psi — gage or differential . . . 5 to 2,500 psi — absolute

Accepts corrosive fluids — both sides

½ % full scale accuracy

Designed for voltage controlled telemetering and other DC systems

PACE
engineering company
13035 Saticoy Street
North Hollywood, California
TRiangle 7-7139

CIRCLE 305 ON READER SERVICE CARD

REPRINTS cont'd

transducers: pin-and-pawl mechanism, magnetic bench-mark system, resolver-type transducer, electrostatic transducer, coded-disc devices, and diffraction gratings. 30 cents.

500—Ready Reference Data Files—I, II, III, 76 pp. The feature here is a special rate for those who purchase all of the Data Files published in CONTROL ENGINEERING through April 1960. The 36 articles included in this package cover analysis, design, and application short-cuts for all phases of the control field. Everyone can use this timeless reference material. $1.35.

499—Ready Reference Data Files—III, 28 pp. Includes the third dozen Data Files published in CONTROL ENGINEERING. Topics range from control of metal properties with eddy currents to electrically signaled valve actuators to stabilization of sampled data systems. 60 cents.

498—Ready Reference Data Files—II, 24 pp. Includes the second dozen data files published in CONTROL ENGINEERING. Topics covered range from analyzing hydraulic servos graphically to using silicon diodes as protective devices. 50 cents.

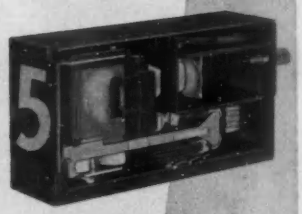
497—Ready Reference Data Files—I, 24 pp. Includes the first 12 data files published in CONTROL ENGINEERING—a diversity of topics from system reliability through the cost of industrial temperature-measuring systems. Each shows how to solve a particular problem. 50 cents.

(Continued on page 263)

BINARY OPERATED READOUT

New! **Operates Direct—No Buffers or Translators Required**

ALL DIGITS CAN BE READ FROM ANY ANGLE



BINA-VIEW Self-Decoding Alpha-Numeric Readout

Applications: Connected directly into computers, teletype, etc.

Features: Electro-magnetic operation, low power (10 milliwatts), accepts BCD code to 6 bits, does own translating.

Specifications: 1⅜″ high character, module size 1¾″ x 3¼″ x 6¾″

Price Complete from $50.00

WRITE TODAY FOR COMPLETE DETAILED INFORMATION

INDUSTRIAL ELECTRONIC ENGINEERS, Inc.
5528 VINELAND AVENUE
NORTH HOLLYWOOD, CALIF.
Representatives in principal cities.

CIRCLE 306 ON READER SERVICE CARD

FREE MANUAL

on function and uses

MERCURY RELAYS

for all loads up to 100 AMPS

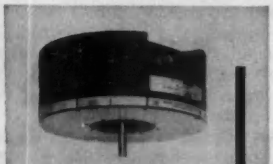


FREE: The standard reference manual on all types and applications of Mercury Plunger Relays. Silent, hermetically sealed, compact, miniature units providing millions of continuous makes and breaks with no maintenance. No pitting or corrosion.

Send for FREE MANUAL and 30-day Free Test details

EBERT ELECTRONICS CORP.
212-18 Jamaica Avenue
Queens Village 18, N. Y.

CANADA: Philips Electronics Industries Ltd., Toronto 17
EXPORT: Philips Export Co., New York City



Up to 262,000 counts per revolution



Up to 32,000 counts per revolution



Lightweight Airborne Model Up to 32,000 counts per revolution

DIGISYN®

PHOTOELECTRIC INCREMENTAL POSITION TRANSDUCERS

Performance:

- Digital pulse output from rotary motion input
- Resolution to 262,000 counts per revolution
- Forward and backward rotation counts
- Provisions for zero reset
- Linear & Non-Linear functions

Typical Applications:

- Precision machines — servo control
- Pulse tachometers
- Shaft position control and monitor
- Circle dividing
- Stable platform position monitor

COMPLETE LINE OF DIRECT-READING BINARY AND SPECIAL ENCODERS AND ACCESSORY EQUIPMENTS ALSO AVAILABLE

Write or call (Boston) COpley 7-8425 for further information

WAYNE-GEORGE
CORPORATION
(ADCON DIVISION)
588 COMMONWEALTH AVENUE • BOSTON 19, MASS.

CIRCLE 309 ON READER SERVICE CARD

UNCOOLED

7

Micron

I R DETECTOR

Now Economically Feasible

BLOCK ASSOCIATES, INC., has developed an indium antimonide Infrared Detector which now makes commercial application of high quality infrared sensing devices economically feasible while affording outstanding technical characteristics.

$45.00

DOES NOT REQUIRE COOLING

CAN BE FABRICATED INTO ALMOST ANY SHAPE OR ARRAY

RESPONSE TIME OF ¼ MICRO SECOND

0.4-7 MICRON SPECTRAL RESPONSE

THESE features make the detector particularly suitable for use with:

LASERS

RAPID SCAN SPECTROMETERS

HIGH SPEED DATA SYSTEMS

IMAGING SYSTEMS

IF your system requires an inexpensive detector in the 0.4-7 micron region with one or a combination of the following characteristics fast response, specially shaped arrays, uncooled detector — then Block Associates photoconductive indium antimonide is the detector which will best suit your needs.

For further information write:

MR. S. BOBO

BLOCK ASSOCIATES, INC.

385 Putnam Avenue
Cambridge, Massachusetts

REPRINTS cont'd

496—**How to Specify Instrument Accuracy,** 8 pp. This basic reprint is aimed at helping the user and maker to develop clear and mutual agreement on allowable instrument errors. Discussions of uncertainties of zero, scale factor, and instantaneous slope aid in the intelligent specification of allowable errors and preferred test procedures. 40 cents.

494—**How to Use the Root Locus in Control System Design,** 12 pp. Another reprint that translates theory into practice. Eight simple rules make locus construction easy, even including the effects of distance-velocity lags. Articles show how to interpret the locus diagram, determine transient response, and use locus techniques with multiloop systems. 45 cents.

489—**Fundamentals of Multivibrators,** 12 pp. Multivibrators are the electronic equivalent of the double-throw electromechanical relay and can perform substantially the same functions (memory, logic, gating, counting), but at enormously higher speeds. They can be built around vacuum tubes, transistors, square-loop magnetic materials, neon tubes, thyratrons, and cryotrons. This covers a broad selection of multivibrator circuits. 45 cents.

488—**A Roundup of Control System Test Equipment,** 24 pp. Specialized control system test equipment divides into three classes: 1) devices that only generate a test signal, 2) systems that both disturb the system and provide a means for evaluating response, and 3) devices that only evaluate control system response. 60 cents.

487—**Survey of Ac Adjustable-Speed Drive Systems,** June 1959, 16 pp. Regarded as constant speed devices, multispeed ac actuators actually take many efficient forms. The recent resurgence of interest in these ac adjustable-speed systems prompted this comprehensive coverage of pole-changing techniques, armature resistance control of wound-rotor motors, slip-frequency injection, use of eddy-current couplings, etc. 50 cents.

486—**A New Way to Select the Best Control-system Control Valve,** 16 pp. This three-article reprint gives rules for selecting the right valve characteristics based on static and dynamic considerations, takes into account the influence of piping on valve performance, and tackles the problem of sizing valves for maximum flow and for control rangeability. 50 cents.

485—**Fundamentals of Tie-Motor Control,** 12 pp. Although high powered synchro-tie systems have been around for a long time, only recently has enough experience been logged to put their design on a scientific, rather than cut-and-try basis. The reprint examines the types of motors that can be used in the light of the application characteristics, and considers the special circuit designs that are required. 30 cents.

484—**Applying Phase-Plane Techniques to Nonlinear System Design,** 16 pp. This series of three articles is designed to teach the use of phase-plane techniques to working system designers, on a practical rather than theoretical basis. It tells how to construct a phase-plane plot, interpret a plot in terms of system performance, and synthesize nonlinear systems using phase-plane techniques. 50 cents.

New!

HALL-EFFECT PRODUCTS

Detection, measurement and control applications requiring rigid electrical and physical conformance will be satisfied by the more than 40 different types of Siemens Hall Generators, each with its particular sensitivity, output and physical configuration.

- ★ Field probes for measurement and control feature low temperature coefficients, high stability, and small size. Ultra thin models are stocked.
- ★ Precision probes are available with 0.2% linearity.
- ★ Units are produced for measuring axial fields in small deep holes.
- ★ Exceptionally high output signalling pickups deliver up to 3½ volts.
- ★ Modulators and multipliers with 0.3% linearity are among the standard units.
- ★ Flux sensitive tape pickup heads with 15 micron gap and high output deliver superior performance without coil windings.



NEW INSTRUMENTATION
Using These Devices

- ★ Model A Gaussmeter measures up to 20,000 gauss without amplifier. Price $168.00
- ★ Model G Precision Gaussmeter, accuracy better than 1% uses rugged lightspot galvanometer. Price $524.00

Write for specifications and prices on these and many other magnetic instruments.

instrument systems corporation

ISC

Halltest Division, *129-07 18th Avenue*
College Point, N. Y. INdependence 1-1000

EMPLOYMENT OPPORTUNITIES

Control ENGINEERING

INSTRUMENTATION AND CONTROL SYSTEMS

MONTHLY QUALIFICATION FORM FOR POSITIONS AVAILABLE

ATTENTION: ENGINEERS, SCIENTISTS, PHYSICISTS

This Qualification Form is designed to help you advance in the control industry. It is unique and compact. Designed with the assistance of professional personnel management, it isolates specific experience in instrumentation and deals only in essential background information. The advertisers listed here are seeking professional experience. Fill in the Qualification Form below.

STRICTLY CONFIDENTIAL

Your Qualification form will be handled as "Strictly Confidential." Our processing system is such that your form will be forwarded within 24 hours to the proper executives in the companies you select. You will be contacted at your home by the interested companies.

WHAT TO DO

1. Review the positions in the advertisements.
2. Select those for which you qualify.
3. Notice the key numbers.
4. Circle the corresponding key number below the Qualification Form.
5. Fill out the form completely. *PLEASE PRINT CLEARLY*
6. Mail to: D. Hawksby, Classified Advertising Div., Control Engineering, Box 12, New York 36, N. Y. (No charge, of course).

COMPANY	SEE PAGE	KEY #
A M F ATOMICS Greenwich, Connecticut	176*	1
AMERICAN MACHINE & FOUNDRY CO. Springdale, Connecticut	268	2
BENDIX CORPORATION Kansas City Division Kansas City, Missouri	266	3
CORNELL ASSOCIATES INC. Chicago, Illinois	266	4
ESQUIRE PERSONNEL Chicago, Illinois	266	5
LEDGERWOOD, EDITOR, BYRON K. New York, New York	262, 268	6
LEEDS & NORTHROP COMPANY Philadelphia, Pennsylvania	266, 268	7
LITTON SYSTEMS INC. Guidance & Control Systems Div. Woodland Hills, California	171*	8
MOOG SERVOCONTROLS INC. Aurora, New York	266	9
PHILCO-TECHREP DIVISION Philadelphia, Pennsylvania	267	10
RAMO WOOLDRIDGE Div. of Thompson-Ramo Wooldridge Inc. Canoga Park, California	269	11
SANDIA CORPORATION Albuquerque, New Mexico	49	12
SELECT PERSONNEL AGENCY INC. New York, New York	266	13
SIKORSKY AIRCRAFT Div. of United Aircraft Corp. Stratford, Connecticut	265	14

* These advertisements appeared in the August issue.

(cut here) (cut here)

CONTROL ENGINEERING MONTHLY QUALIFICATION FORM FOR POSITIONS AVAILABLE

Personal Background

NAME .....

HOME ADDRESS .....

CITY..... ZONE..... STATE.....

HOME TELEPHONE.....

Education

PROFESSIONAL DEGREE(S) .....

MAJOR(S) .....

UNIVERSITY .....

DATE(S) .....

FIELDS OF EXPERIENCE (Please Check) 961

- ☐ Aerospace Control
- ☐ Components
- ☐ Computer Design
- ☐ Computer Application
- ☐ Computer Programming
- ☐ Control Theory
- ☐ Data Communication
- ☐ Display
- ☐ Electronic Circuitry
- ☐ Flight Instrumentation
- ☐ Guidance Systems
- ☐ Hydraulics
- ☐ Industrial Control
- ☐ Logic Design
- ☐ Machinery Control
- ☐ Man Machines
- ☐ Motor Control
- ☐ Nuclear
- ☐ Numerical Control
- ☐ Optics
- ☐ Pneumatics
- ☐ Process Control
- ☐ Process Instrumentation
- ☐ Servomechanisms
- ☐ Simulation
- ☐ Solid State Devices
- ☐ Switching
- ☐ Systems Analysis
- ☐ Other .....

CATEGORY OF SPECIALIZATION

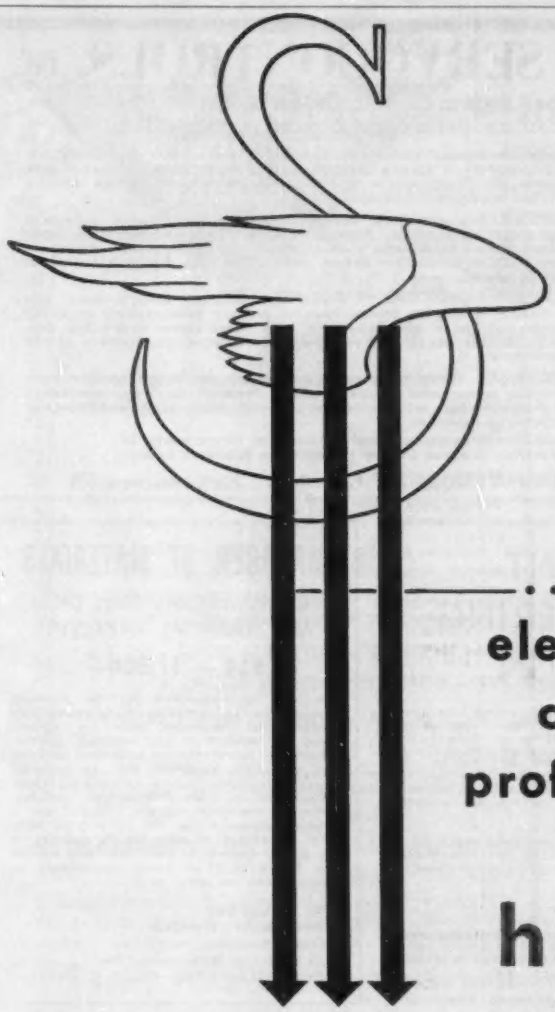
Please indicate number of months experience on proper lines

	Technical Experience (Months)	Supervisory Experience (Months)
RESEARCH (pure, fundamental, basic)	.....	.....
RESEARCH (Applied)	.....	.....
SYSTEMS (New Concepts)	.....	.....
DEVELOPMENT (Model)	.....	.....
DESIGN (Product)	.....	.....
MANUFACTURING (Product)	.....	.....
FIELD (Service)	.....	.....
SALES (Proposals & Products)	.....	.....

CIRCLE KEY NUMBERS OF ABOVE COMPANIES' POSITIONS THAT INTEREST YOU

1 2 3 4 5 6 7 8 9 10 11 12

pioneer and leading manufacturer of rotary wing aircraft



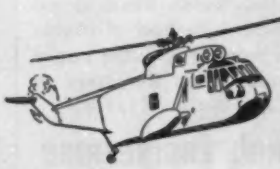
. . . at **SIKORSKY**
electronic engineers can broaden their professional horizons in the field of
helitronics

Today, as Sikorsky Aircraft's activities expand in significance and scope, particular emphasis is being directed to a sphere of activity which we term "*helitronics*". This area embraces a blending of two major technologies: *heli*copters and elec*tronics*. Specifically, helitronics means the integration of guidance and navigation systems, specialized electronic search and detection equipment to enhance the mission capability of the helicopter; specialized sensors and automatic controls to increase its versatility as an optimum military weapon system and a commercial carrier.

The need for more sophisticated electronic systems offers exceptional opportunities to competent electronic engineers with particular skills in: design • instrumentation • test • development • air-borne systems • production and service support equipment • trainers and simulators.

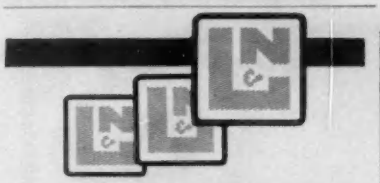
Unusually interesting openings as Avionics Instructors also exist for men with aircraft electronics experience and a desire to teach.

If you are interested in these career opportunities, please submit your resume, including minimum salary requirements, to L. J. Shalvoy, Personnel Department.



SIKORSKY AIRCRAFT STRATFORD, CONNECTICUT
DIVISION OF UNITED AIRCRAFT CORPORATION

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.



ENGINEERS AND SCIENTISTS

G-R-O-W

WITH THE FIRM THAT IS BUILT ON RESEARCH

Leeds & Northrup Co., as a result of continued growth, now has openings for college graduates at the Bachelor, Master and Doctoral levels. Electrical, Chemical, Mechanical, or Physics degree preferred.

If you enjoy doing creative work at a truly professional level and have 2 to 10 years' experience in:

- Measurement and Control of Industrial Processes
- Data Processing
- Steam Power
- Systems Analysis
- Servomechanisms
- Analytical Instrumentation
- Mechanical Design
- Analog or Digital Computers
- Solid State Electronics

We would like to talk with you about openings in:

RESEARCH & DEVELOPMENT
SYSTEMS ENGINEERING
MARKET DEVELOPMENT
PRODUCT ENGINEERING
SALES ENGINEERING

Send Complete Resume To:
WAYNE L. BESSELMAN
Coordinator of Technical Employment

LEEDS NORTHRUP
Instruments • Automatic Controls • Furnaces
4850 STENTON AVENUE
PHILADELPHIA 44, PA.

An Equal Opportunity Employer

MOOG SERVOCONTROLS, INC.

Our continued growth in both the industrial and military electro-hydraulics fields has created opportunities for:

PROTOTYPE ENGINEER—Specify electro-hydraulic servo components and direct prototyping operations preparatory to volume production. 5 or more years experience with servo mechanisms essential. Familiarity with electronics instrumentation and military specs necessary. Project experience desirable.

RELIABILITY ENGINEER—Evaluate basic design parameters, considering materials, tolerances, stress and statistical analysis. Physics, M.E. or E.E. degree and grad. work essential. 4 years background in reliability or electro-mechanical systems testing or design analysis. Key position conducting design evaluations and directing testing of intricate electro-hydraulic components.

PRODUCT AND MARKET DEVELOPMENT ENGINEER—Explore Moog's entry into totally new fields. Number 2 man in crucial area of product development, requiring strong technical background and market "curiosity". 4-8 years servo, hydraulics, controls or instrumentation experience. Must have "feel" for unusual applications of our electro-hydraulics know-how.

SERVO DESIGN ENGINEER. Senior-Technical responsibility for design and development of electro-hydraulic components. Work involves dynamic analysis, component specification, design mechanization, test evaluation, proposal preparation, and customer contact. Similar background essential.

These positions offer you unusual professional advancement in our engineering oriented Company, located in suburban Buffalo

MOOG SERVOCONTROLS, INC. **East Aurora, N. Y.**

PLANT ENGINEERING DESIGN

Bendix of Kansas City, Missouri has immediate openings for graduate engineers with a minimum of three to five years experience in the design and preparation of specifications for the application of special electrical, electronic, pneumatic and transducer controls involving industrial plant utility and production processes.

These are responsible positions for engineers who enjoy following projects from initial definition through procurement and installation.

Ours is one of the nation's most vital industries. We offer unusually generous company benefits in a Midwestern community which is famous for its beauty and low cost of living. All replies will be strictly confidential.

For Personal Interview Send Complete Resume to:

Mr. D. M. Bowen
Box 303-XD

THE Bendix CORPORATION

KANSAS CITY DIVISION
95th & Troost
Kansas City 41, Missouri

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

MANAGER OF MATERIALS

COMMERCIAL ELECTRO-MECHANICAL INDUSTRY

$14 — 17,500+

You will be responsible for the planning and direction of activities of personnel and departments concerned with the various areas of production and material control. Scheduling manufacturing activities, ordering and purchasing materials, etc. As top man in division, you report to vice-president. Background in electro-mechanical manufacturing or electronic industry. If you are a "heavy" administrator and have good technical knowledge of materials in quantity in the electro-mechanical field—you can do this job. Please direct all replies immediately by phone, wire, or letter to:

Mr. Michael Bass
Vice President Operations
Cornell Associates, Inc.
14 E. Jackson Blvd.—Suite 1206
Phone WAbash 2-7580—Chicago 4, Illinois.

MANAGER MOTOR ENGINEERING
$15,000 Per Year

Experience in motor design, and some supervision desirable. Will be expected to develop and maintain an expanding engineering department. Vacationland area. Client assumes all employment expense. Send resume in complete confidence.

ESQUIRE PERSONNEL
212 S. State St., Chicago 4, Ill.

ENGINEERS—DO YOU WANT
More Opportunity—Higher Salary
Or a new Location?
REGISTER WITH US!
NO REGISTRATION OR CONSULTATION FEES
Fees and Relocation Expenses Usually Paid By The Company
MANY OPENINGS—TOP FIRMS
SELECT PERSONNEL AGY
507—5th Ave., N. Y. 17, N. Y. MU 7-8140

effective

ENGINEER RECRUITMENT ADVERTISING

depends on

ENGINEERING READERSHIP

Where your recruitment program calls for qualified engineers in the control field, there is no more efficient method of reaching them than through the pages of the publication they pay to read. . . .

CONTROL ENGINEERING

Classified Advertising Division
Post Office Box 12
New York 36, New York

ELECTRONIC ENGINEERS
MATHEMATICIANS
PHYSICISTS

PHILCO TECHREP DIVISION

Now Forming Nucleus Group To Develop & Manage Systems Engineering On America's Various Defense Projects!

Who Are Ready to GO...and Able to GROW

• Choose From These Key Locations

- **Philadelphia, Pa.**
- **Boston, Mass.**
- **Washington, D. C.**
- **Palo Alto, Calif.**
- **Pensacola, Fla.**
- **Montgomery, Ala.**

plus many other choice U. S. locations

Broadly speaking, the men we are looking for will direct their professional efforts to developing and establishing systems engineering concepts, standards, and criteria for the overall operation of computer equipment and systems.

These are long term career positions offering first rate promotional opportunities to U.S. Citizens "ready to go and able to grow" with America's foremost electronic field engineering organization.

Intermediate and Senior Level Positions Available For Men Who Are Able To Perform Systems Engineering and Development Work In The Following Areas:

• ESS • SAGE • BIRDIE • BOMARC • MISSILE MASTER • ALRI • SEAWARD EXTENSION • LARGE COMMUNICATIONS SYSTEMS • LOW DATA RATE INPUT • NIKE

REQUIRED QUALIFICATIONS: B.S., M.S. or Ph.D. in Electrical Engineering, Mathematics, or Physics

SALARIES OPEN

PROGRAM SYSTEMS ANALYSTS

To develop requirements and prepare specifications for design evaluation tests, to examine operation of experimental and production models of the system. Design of system tests and special test operating procedures. Will participate in live system testing of various complex systems. Will analyze test data and prepare documents which spell out results and conclusions to be derived from system tests. These conclusions should cover adequacy of the design logic and implementation of equipments, computer programs, and control manning.

RADAR SYSTEMS ENGINEERS

To integrate varied data acquisition equipment into complex electronic control systems.

TELECOMMUNICATIONS ENGINEERS

To design and develop advanced communications subsystems of ground electronic control system complex.

SENIOR PROGRAMMERS

Will be responsible for the overall planning and supervision of computer programs. Will assign, outline and coordinate work of programmers and write and debug complex programs involving mathematical equations. Requires experience in the operation and programming of large electronic data processing systems, such as the AN/FSQ-7N8, IBM 700 series, or Philco S-2000 series.

COMPUTER PROGRAMMERS

To develop and/or analyze logic diagrams, translate detailed flow charts into coded machine instructions, test run programs and write descriptions of completed programs. Requires experience in the operation and programming of large electronic data processing systems, such as the AN/FSQ-7N8, IBM 700 series, or Philco S-2000 series.

TECHNICAL WRITERS

To write and publish technical reports on Communications, Radar, Fire Control Systems, Electrical and Mechanical Devices and Computers.

CABLE ENGINEERS

To resolve varied grounding and shielding problems of complex electronic equipments.

RADAR DESIGN ENGINEERS

To work on advanced designs—to develop receivers using parametric amplifiers.

SUB-SYSTEMS TEST ENGINEERS

To plan, prepare and generate specifications for sub-systems test, data reduction and analysis programs. Will be responsible for the preparation of test plans, installation of equipment, test instrumentation, collection of test data and analysis of results. Resolve incompatibility and interface engineering problems.

SYSTEMS TEST ENGINEERS

To plan, prepare and generate system test, data reduction, and analysis specifications. Develop methods and procedures for test implementation. Coordinate between interested agencies, and resolve problems between the specifications, test methods and actual procedures in use.

Direct Resumes In Confidence To

Dept. CE

D. E. DIMMIG
Employment Manager

PHILCO TECHREP DIVISION

P. O. Box 4730 **Philadelphia 34, Pa.**

ALL QUALIFIED APPLICANTS WILL RECEIVE CONSIDERATION FOR EMPLOYMENT WITHOUT REGARD TO RACE, CREED, COLOR OR NATIONAL ORIGIN.

GROW

WITH THE FIRM THAT
PIONEERS *in* PRECISION

Advanced Data Handling

ENGINEERS

With Systems Background

GROWTH OPPORTUNITIES

. . . await qualified senior level engineers to assist L & N's able staff in the development and engineering of LN3000 Computer Control Systems for Industrial Processes in the Power, Petro-chemical, Steel and Ceramic industries. B.S. or M.S., preferably in E.E. required PLUS several years' design & development experience on data handling circuits incorporating digital computer techniques.

Send Resume to WAYNE L. BESSELMAN, Coordinator Technical Employment

Pioneers in Precision ... **LEEDS NORTHRUP**

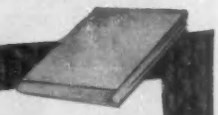
Instruments • Automatic Controls • Furnaces
4901 Stenton Avenue Philadelphia 44, Pa.
An Equal Opportunity Employer

Just Published

ANTENNA ENGINEERING HANDBOOK

Prepared by a Staff of Specialists
Edited by HENRY JASIK
President, Jasik Laboratories, Inc.

A vast amount of information relating to antennas and antenna design is brought to you in this practical Handbook. From basic fundamentals to modern design applications the book offers the kind of detailed treatment necessary for successfully working in today's complex field of antenna engineering. Important data on many types of commercial antennas, and a number of developments in the field of military applications are included. This authoritative guide includes material on long wire, slot, loop, helical, horn, reflector, and scanning antennas. Engineering applications of receiving, transmitting, radar, aircraft, VHF and UHF communications antennas are fully covered. Treated, too, are such important advances as frequency independent antennas, surface wave antennas, scanning antennas, radio telescope antennas, and others. Transmission lines, impedance matching and broadbanding, radome problems, propagation problems, and other special topics round out the comprehensive coverage of the Handbook. **1013 pp., 993 illus. & charts. $22.00**



NUCLEAR PULSE SPECTROMETRY

Just Published. Gives clear, concise explanations of electronic systems, circuits, and methods used in counter and ionization chamber devices. Treats nuclear radiation detectors, pulse amplifiers, pulse-height and pulse-time distribution analyzers, coincidence systems, data storage devices, and other topics. Includes circuit diagrams, engineering data, etc. **By R. Chase, Instrumentation Div., Brookhaven Natl. Lab. 226 pp., 119 illus., $8.50**

ENGINEERING DATA FOR PRODUCT DESIGN

Just Published. A wealth of engineering data — charts, formulas, tables and vital facts—is now made available in this time-saving manual of design information. The book's material—selected for its broad scope and practical value—brings you abreast of modern aspects, including dielectric heating, metal whiskers, hi-temp spring materials, and others. **Edited by D. Greenwood,** *Product Engineering.* **448 pp., 635 illus., $10.00**

FREE EXAMINATION

McGraw-Hill Book Co., Dept. CON-F9
327 W. 41st St., New York 36, N. Y.

Send me book(s) checked below for 10 days' examination on approval. In 10 days I will remit for book(s) I keep plus few cents for delivery cos'ts, and return unwanted book(s) postpaid. (We pay delivery costs if you remit with this coupon—same return privilege.)

☐ Jasik—Antenna Engrg. Handbook—$22.00
☐ Chase—Nuclear Pulse Spectrometry—$8.50
☐ Greenwood—Engineering Data for Product Design—$10.00

Name .....
Address .....
City .....Zone ....State.....
Company .....
Position .....

For prices and terms outside U.S. write McGraw-Hill Intl., N.Y.C. 36 CON-F9

MANAGER OF ENGINEERING

Product engineering responsibility for new, complex, electronically controlled mechanical device. Applicant needs broad experience in circuitry, mechanics and hydraulics with emphasis on electronic control. Manufacturing experience necessary to facilitate the transition of development work into production. Manager of Engineering for new business unit in Chicago.

AMF has more than tripled in size in the past 10 years. This new product can help us do it again. Salary $15,000 to $20,000.

Please direct your inquiry to Mr. Richard H. Parker

RESEARCH & DEVELOPMENT DIVISION

AMERICAN MACHINE & FOUNDRY COMPANY

689 Hope Street
Springdale, Connecticut

EXPAND

YOUR VIEW OF THE CONTROL FIELD

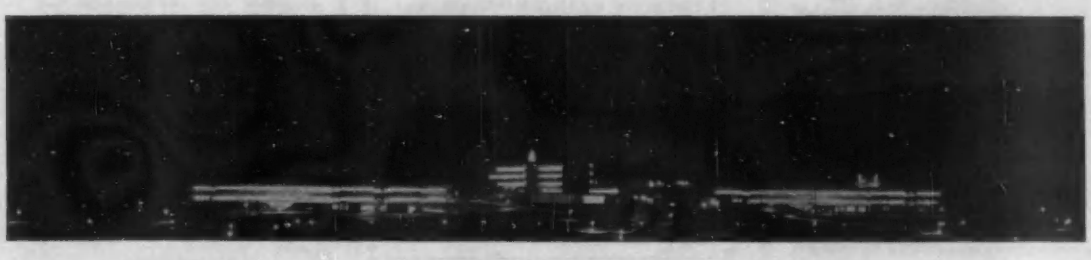
We need a young process control engineer with a flair for writing to fill a position as Assistant Editor on the staff of Control Engineering. He must have an engineering degree and a good knowledge of the fundamentals of automatic control theory, plus a familiarity with the techniques and equipment used for petroleum and chemical process control. His responsibility will be to keep himself and CtE's readers on the forefront of control in raw materials processing. Editorial offices are in New York City and some time will be spent traveling to technical meetings and to leading users and manufacturers of control equipment.

If you fit the qualifications and want a unique opportunity to become one of the best informed men in the control field, send your resume to

Byron K. Ledgerwood
Editor
Control Engineering
330 W 42nd Street
New York 36, N. Y.

Ramo-Wooldridge designs and produces data processing systems, computers, display devices, man-machine communication consoles, and related peripheral equipment for military and commercial applications.

Select openings exist in systems analysis and applications, computer programming, equipment design and applications engineering.



All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin. Write for our free career brochure **An Introduction to Ramo-Wooldridge.** Address Mr. Theodore E. Coburn at **Ramo-Wooldridge,** a Division of Thompson Ramo Wooldridge Inc. 8433 Fallbrook Avenue, Canoga Park, California.

"TAB", SILICON 750MA *DIODES

Factory Tested Gtd.!

General Purpose Special 35¢ each — .400 PIV at 300 MA 20 for $6

rms/piv 17/25 10¢	rms/piv 35/50 14¢	rms/piv 70/100 24¢	rms/piv 140/200 29¢
rms/piv 210/300 39¢	rms/piv 280/400 50¢	rms/piv 350/500 64¢	rms/piv 420/600 74¢
rms/piv 490/700 87¢	rms/piv 560/800 93¢	rms/piv 630/900 $1.10	rms/piv 700/1000 $1.5

Low Priced • T200 SILICON DIODES rated 380piv/266rms @ 200Ma @100°C 36¢ each; 10 for $3.25; 100 for $27; 1000 for $230

Cap. or Batty. Derate 20%

"TAB" FOR TRANSISTORS & DIODES! ! ! !
FULL LENGTH LEADS

Factory Tested & Guaranteed! U.S.A. Mfgrd!

PNP HiPower 15 Amp Max 25°C 2N441, 2N277 $2 @. 2N442, 2N278, $3 @. 2N173 or 2N443 $4 @. 2N174 $5 @. 3 Amp. 2N155, 2N156, 2N255, 2N256 2N307, 2N554, 80 @. 20/$15. 100/$65.

2N123 PNP ¢45 @ . . . . .12 for $5. 100/$37
2N292, 2N293 NPN ¢45 @ 12 for $5. 100/$35
2N223 PNP 80¢ @ . . . 12 for $9. 100 for $65
2N170/$180. 2N270/95¢. 2N670/$1.60
2N671/$2. Kit PNP or NPN ¢39 @. 3 for $1
Round or Diamond Base—Mica Wfr. Kit ¢30 @
Heat Sink with Fins 80 sq." $1.75. Kit Glass Diodes Computer Grade ¢20 @ 8 for $1. 100 for $7. 1000 for $50.

GENERAL PURPOSE—PNP—COMPUTER GRADE! Use as Amplifier—Oscillator—IFT RF, IF Amp. Driver—Logic—Servoamp—Power Supply Pulse Amplifier or High Current Switch Vcb, Vce, Veb Approx 40V

GP 3c rated 300Mw ¢85 @ . .10 for $5. 100/$39
GP10C rated one watt 90¢. @ .6 for $5 100/$63

POWER DIODES—STUDS 50Piv/35Rms FACTORY TESTED—GTD!

1.5 Amp ¢30 @ . . . . . 100 for $27
3.0 Amp ¢50 @ . . . . . 100 for $45
6.0 Amp $1.50 @ . . . . . 100 for $100
12 Amp $1.45 @ . . . . . 100 for $125
35 Amp $2.30 @ . . . . . 100 for $200
70 Amp $3.90 @ . . . . . 50 for $175
240 Amp $4.50 @ . . . . . 50 for $220

*Derate 20% for Capacitive & Battery Load! Amp Ratings for Studs on Heat Sink!!!

! GTD SILICON—5U4G—SPECIAL!!!—GTD!
OCTAL SILICON DIODE REPLACEMENT 1120Rms/1600Piv $3.90 @. 3 for $10

"TAB" TERMS! Money Back Guarantee! One 17th year. $2 min. order F.O.B. N.Y.C. Add shpg charges or for C.O.D. 25% Dep. Prices shown subject to change.

111-MJ LIBERTY ST., N.Y. 6, N.Y.

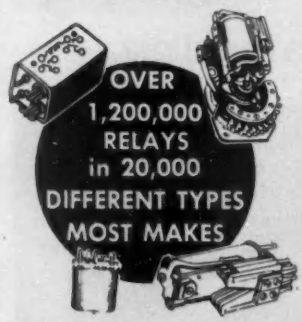
Send 25c for Catalog

PHONE RECTOR 2-6245

CIRCLE 276 ON READER SERVICE CARD

SAVE TIME & EXPENSE ON PURCHASING

RELAYS



- PRODUCTION QUANTITIES IN STOCK
- DELIVERY ON OFF-THE-SHELF ITEMS WITHIN 48 HOURS. DELIVERY WITHIN ONE WEEK ON RELAYS REQUIRING ASSEMBLY AND/OR ADJUSTMENT.

WE DELIVER RELAYS NOT PROMISES

SEND FOR CATALOG C

Universal RELAY CORP.

42A White St., New York 13, N. Y. • WAlker 5-9257

CIRCLE 277 ON READER SERVICE CARD

SEARCHLIGHT SECTION

CLASSIFIED ADVERTISING

BUSINESS OPPORTUNITIES - EQUIPMENT - USED or RESALE

DISPLAYED RATES

The advertising rate is $20.80 per inch for all advertising appearing on other than a contract basis. Contract rates quoted on request.

AN ADVERTISING INCH is measured ⅞ inch vert. on one col., 3 columns—30 in. to a page.

EQUIPMENT WAITED or FOR SALE ADVERTISMENTS acceptable only in Displayed Style.

UNDISPLAYED RATES

$2.10 a line, min. 3 lines. To figure advance payment count 5 average words as a line.

BOX NUMBERS count as one additional line in undisplayed ads.

DISCOUNT OF 10% if full payment is made in advance for four consecutive insertions of undisplayed ads.

Wilgreen

can deliver **Amphenol Bendix Cannon**



CONNECTORS FITTINGS & CLAMPS

We stock more than 5,000,000 MS/AN CONNECTORS . . . of 50,000 variations! In PRODUCTION QUANTITIES . . . we sell BELOW "O.E.M." PRICE . . . and offer IMMEDIATE "OFF-THE-SHELF" DELIVERY!

FREE . . . Send for latest brochure and list price chart

WILGREEN INDUSTRIES, Inc.
102 Warren Street, New York 7, N. Y.
WOrth 4-2490-1-2 Wire: FXK

CIRCLE 278 ON READER SERVICE CARD

• KLYSTRON SPECIAL •

726 B. C.	$15.00	2K50	$72.00
5721	125.00	2K54	15.00
6115	50.00	2K55	25.00
6116	75.00	2K56	50.00
6390	175.00	3K21	150.00
2K22	22.50	QK185	35.00
2K23	22.50	QK290	350.00
2K25	9.00	QK291	350.00
2K28	27.50	QK292	350.00
2K29	27.50	QK293	350.00
2K33A	200.00	QK294	350.00
2K33B	300.00	QK295	450.00
2K39	170.00	V23	450.00
2K41	75.00	V27	600.00
2K42	150.00	V28	975.00
2K43	144.00	V45	450.00
2K44	100.00	V270	125.00
2K45	25.00	VA94	350.00
2K48	50.00	X13B	325.00

LIBERTY ELECTRONICS, Inc.
582 Broadway New York 12, N. Y.
WAlker 5-6000 Cables: TELSERSUP

CIRCLE 279 ON READER SERVICE CARD

DID YOU FIND THE COMPONENTS and/or TEST EQUIPMENT YOU NEED?

If what you're looking for is not advertised in the "Searchlight Section" . . . send us your requirements and we'll find it for you. No charge or obligation . . . of course.

ADVANCE ELECTRONICS CO.
79 CORTLANDT STREET
NEW YORK 7, N. Y.
Please help me locate the following:

. . . . . .
. . . . . .
. . . . . .
. . . . . .

Name. . . . . Title. . . . . .
Company . . . . . .
Address . . . . . .
City. . . . . Zone. . . . State. . . . . .
☐ Please send me your latest catalog and add my name to your mailing list.

CIRCLE 280 ON READER SERVICE CARD



if you purchase TUBES & SPECIALIZED ELECTRONIC COMPONENTS...

. . . THE *NEW* FALL EDITION OF THE BARRY GREENSHEET IS A MUST!

Circle Reader Service Card No. 275 for your copy.
A Complete 48 Page Electronics Buyers' Guide

BARRY ELECTRONICS CORP.
512 Broadway • New York 12, N. Y. • WAlker 5-7000
Cable: Barryject, NY • Teletype: NY 1-3731

CIRCLE 275 ON READER SERVICE CARD

AC SWITCHBOARD METERS GE 8AB 18

4½" sq. flush mtg. 1½ accuracy. 60-400 cy. 270 deg. standard white scale. Latest model.

0 - 25 amperes AC. $13.95
to be used with external C.T. 5:1
0 - 5 amperes AC. $19.95
0 - 150 volts AC. $24.95
0 - 250 volts AC. $25.95

FRAHM FREQUENCY METER MODEL 4997

3½" rd flush bakelite 380-420 cycles 100-150 volts AC, 9 vibrating reeds. $7.95

DIGITAL READOUT Electro Instruments, Inc. 3 digit model #2003-M-28. Numerals ½" ht. O.A. dimensions 5" x 2¼" x 1¾". . . $14.95

Quantity discounts available. All mdse. new. We pay shipping chgs. on prepaid orders.

LEO SAGAL CO.
860 GLENMONT AVE. LOS ANGELES 24, CALIF.

CIRCLE 281 ON READER SERVICE CARD

JOB ADVANCING?

Make the move to your new job easy and worry-free with the Burnham Van Personalized Moving Plan—the most helpful plan you ever saw.

Send for the free, 16-page booklet which gives you moving tips on how to pack, a checklist of things to do.

Write for your copy today: Charles E. Swann.

BURNHAM VAN SERVICE
1633 Second Avenue, Columbus, Georgia

CIRCLE 282 ON READER SERVICE CARD

FOR SALE

$.0015X^3 + .030X^2 + .18X + 1 = 0$ reduced to $(.0224X^2 + .113X + 1)(.067X + 1) = 0$ in 20 Seconds with the Cubic Solver Slide Chart. Reduce cubics easy and quick to $(AX^2 + BX + 1)(CX + 1) = 0$. Send $2.98—F. W. Jackson, 318 Maple Ave., Drexel Hill, Pa.

DID YOU KNOW . . . ?

That when buyers are in the market for a specific piece of used or rebuilt equipment . . . they turn to the

SEARCHLIGHT SECTION

ADVERTISING IN THIS ISSUE

AMP Incorporated 220
Adams & Westlake Co., Inc..... 272
Airborne Accessories Corporation Electronics Division 232
Aldolf Meller Company..... 10
Allen-Bradley Co. 219
Allied Electronics Subsidiary of Allied Radio 256
Allis-Chalmers, Hydraulic Division.. 51
American Bosch Arma Corporation.. 66
American Optical Company..... 101
Ampex Instrumentation Products Co. Fourth Cover
Anelex Corporation 216
Assembly Products, Inc..... 242
AstroData Inc. 2
Atomics International 240
Automatic Electric 52
Automatic Switch Co..... 17

B/W Controller Corporation, The. 236
Bailey Meter Co..... 96
Barber-Colman Company Wheelco Industrial Instruments Div. 84, 85
Electrical Components Div..... 255
Barksdale Valves 20
Barton Instrument Corporation.... 22
Beaver Precision Products Inc..... 196
Beckman Instruments, Inc., Helipot Div. 90
Beckman Instruments, Inc., Scientific and Process Instruments Division. 107
Bell Inc., F. W..... 252
Bendix Corporation, Eclipse-Pioneer Division 208, 209
Block Associates, Inc..... 263
Bourns, Inc. 75
Bowmar Instrument Corporation.... 83
Brush Instruments, Div. of Clevite Corp. 15
Burroughs Corporation, Electronic Tube Division 91

Calibration Standards Corporation.. 235
Clifton Precision Products Co., Inc. Third Cover
Comar Electric 16
Computer-Measurements Co. 5
Computer Systems, Inc..... 29
Conoflow Corporation 54
Consolidated Electrodynamics 203
Control Indicating Corporation.... 247
Cubic Corporation, Industrial Division 50
Curtiss-Wright Corporation Princeton Division 260
Cutler-Hammer Inc. 98, 99

Datascope Corporation 40
Daven Co., The..... 252
Daystrom, Incorporated, Potentiometer Division 11

Delavan Manufacturing Company.. 227
Delco Radio Division of General Motors 210, 211
Delta Design, Inc..... 258
Di/An Controls, Inc..... 256
Donner Scientific Company..... 111
Douglas Aircraft Company..... 233
Dynamics Research Corporation.... 260

Ebert Electronics Corp..... 262
Edison Industries, Thomas A. Instrument Division 191
Elastic Stop Nut Corporation of America 249
Electro Instruments, Inc..... 56
Electro Switch Corp..... 204
Electronic Associates, Inc..... 114
Electronic Engineering Company of California 258
Electronic Measurements Company, Inc. 205
Elgin National Watch Company.. 199
Erie Instrumentation, Erie Pacific Division 42
Essex Wire Corporation, RBM Controls Div. 94

Fairbanks Morse, Electronics Division 81
Fairchild Controls Corp..... 48
Fairchild Semiconductor 95
Fenwal Incorporated 33, 34, 35, 36
Fielden Electronics, Inc..... 250
Fisher Governor Company.....70, 71
Foxboro Company, The.....92, 93
Friden, Inc. 194

General Ceramics, Division of Indiana General Corporation 74
General Dynamics/Electronics 240
General Dynamics/Electronics, Information Technology Division. 63
General Electric Company Computer Department 68
Rectifier Components Department 108, 109
General Instrument Corporation, Semiconductor Division 45
General Metrics Company 246
Genisco Incorporated 244
Genistron A Subsidiary of Genisco Incorporated 254
Gertsch Products, Inc. 218
Graphic Controls Corporation..... 259
Gurley, W. & L. E..... 248

Halliburton Company 7
Hamilton Standard Division, Electronics Dept., United Aircraft Corp. 112
Hays Corporation, The 225
Hewlett-Packard Company 67
Holtzer-Cabot Motor Division, National Pneumatic Co., Inc..... 251

Hoover Company, The, Electronics Division 30, 31
Hoskins Manufacturing Company.. 6
Houdaille Industries Inc. 64
Hughes Aircraft Company.....57, 250
Hydro-Aire Division of Crane...254, 255

Industrial Electronic Engineers, Inc. 262
Industrial Test Equipment..... 257
Industrial Timer Corporation..... 80
Inland Motor Corporation of Virginia 89
Instrument Systems Corporation... 263
International Business Machines.... 212
International Rectifier Corporation.. 197

Kearfott Division, General Precision, Inc. 239, 241
Kidde Aero-Space Division, Walter Kidde & Company, Inc.... 244
Kintel, Division of Cohu Electronics Inc. 1, 53
Krohn-Hite Corporation 253
Kulite-Bytrex Corporation 258

Lear, Electro-Mechanical Division.. 198
Ledex Incorporated 103
Librascope, Division of General Precision, Inc...Second cover
Lincoln Laboratory 256
Line Electric Co. 14
Litton Systems, Inc. Division of Litton Industries 102
Los Alamos Scientific Laboratory... 32
Ludlow Papers 238

MB Electronics, Division of Textron Electronics, Inc. 189
Mason-Neilan Division of Worthington Corporation 12, 13
Massa A Division of Cohu Electronics, Inc. 261
McGraw-Hill Book Company, Inc... 246
Metal Bellow Corporation 235
Micro Switch, A Division of Minneapolis-Honeywell 187, 188
Micro Systems Incorporated..... 211
213, 215
Minneapolis-Honeywell 44, 65, 242
Boston Division 86
Heiland Division 237
Minnesota Minning and Manufacturing Company, Magnetic Products Div. 82
Mnemtron Corporation 257
Muirhead & Co., Limited..... 234
Mycalex Electronics Corporation... 62

National Acme Company, The.... 104
Non-Linear Systems, Inc.....76, 77
Norbatrol Electronics Corp..... 252

MERCURY to MERCURY

failure free



1040 time delay relay. Contact normally open. Coils available to 440 volts A.C.

ADLAKE relays with mercury-to-mercury contacts eliminate most failures due to low contact pressure, contact burning, pitting or sticking . . . are available with fixed time delay in make or break and make and break. Maximum delay is 20 minutes. Contacts available normally open or closed. Load relays are quick acting . . . have normally open or closed contacts. Single pole—Single throw; Double pole, Single throw*; and Three pole, Single throw* arrangements are available. Mail coupon for catalog of Adlake mercury displacement relays.

*Independent circuits. Visit our booth #933 at the I.S.A. Show

A+ Adlake®

The Adams & Westlake Company, Dept. L-3409
Relay Division, Elkhart, Indiana

NAME

COMPANY

ADDRESS

CITY AND STATE

Nordern Division, United Aircraft Corporation 59

Offner Electronics Inc. 73

Pace Engineering Company 262
Panellit a division of ISI Incorporated 88
Philbrick Researchers, Inc., George A. 232
Philco Corp., Lansdale Division 41
Potter & Brumfield 113

RBM Controls Division, Essex Wire Corporation 94
Radio Corporation of America Semiconductor & Materials Division ... 61, 200, 201, 206, 207
Republic Flow Meters Co. 243
Rheem Electronics Division of Rheem Manufacturing Company. 28
Rosemount Engineering Company .. 192

Sanborn Company, Industrial Division 55
Sandia Corporation 49
Seneca Falls Machine Co. 202
Servo Corporation of America 87
Sigma Instruments, Inc. 230
Silicon Transistor Corp. 195
Skinner Electric Valve Division .105, 106
Sola Electric Co. 214, 215
Stevens Arnold Incorporated 190
Struthers Dunn, Inc. 226
Superior Tube Company 46
Sylvania, Subsidiary of General Telephone & Electronics 79

Taber Instrument Corporation 245
Tally Register Corporation 43
Taylor Instrument Companies .. 118, 119
Tektronix Inc. 58
Telex/Aemco, Division of Telex, Inc. 39
Texas Instruments Incorporated .. 8, 9
Thermo Electric Co., Inc. 69
Thompson Controls, Inc. 248
Thompson Ramo Wooldridge Computer Company 24

Transitron Electronic Corporation .. 217
Trinity Equipment Corporation 37
Tung-Sol Electric Inc. 116

United Electric Controls Co. 231

Vectrol Engineering, Inc. 251
Veeder-Root, Inc. Electronic Controls Division 100
Vickers Incorporated 97
Vidar Corporation 78
Victor Electronics Division, Victor Adding Machine Co. 110

Wallace & Tiernan Inc. ... 38, 228, 229
Walter Kidde & Co. Inc., Kidde Aero Space Division 244
Wayne-George Corporation 262
Westinghouse Electric Corp., Semiconductor Dept. 18, 19
Weston Hydraulics Limited, A Subsidiary of Borg-Warner Corporation. 47
Westronics, Inc. 193

•

CLASSIFIED ADVERTISING
F. J. Eberle, Business Manager

EMPOYMENT OPPORTUNITIES .. 265-269
(For Sale)
(Special Services)

ADVERTISERS INDEX

Advance Electronics Co. 270
American Machine & Foundry Co. 268

Barry Electronics Corp. 270
Bendix Corporation, Kansas City Div. 266
Burnham Van Service Inc. 270

Cornell Associates Inc. 266

Esquire Personnel 266

Ledgerwood, Editor, Byron K. 268
Liberty Electronics Inc. 270
Leeds & Northrop Co. 266, 268

Moog Servocontrols Inc. 266

Philco, Techrep Div. 267

Ramo Wooldridge, Div. of Thompson-Ramo Wooldridge Inc. 269

Sagal Company, Leo 270
Select Personnel Agency Inc. 266
Sikorsky Aircraft, Div. of United Aircraft Corp. 265

TAB 270

Universal Relay Corp. 270

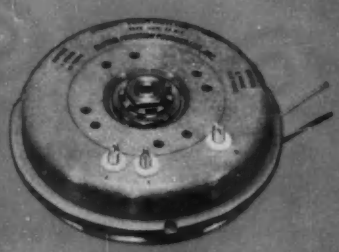
Wilgreen Industries 270

DISTRICT MANAGERS

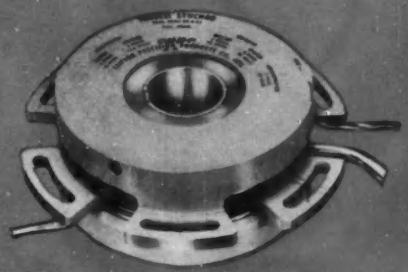
ATLANTA 9: Robert C. Johnson, 1375 Peachtree Street N.E., 875-0523
BOSTON 16: Peter B. Stien, McGraw-Hill Bldg., Copley Square, COngress 2-1160
CHICAGO 11: Milton J. Steinbraker, 645 N. Michigan Ave., MOhawk 4-5800
CLEVELAND 13: Edward H. Walker Jr., 55 Public Square, SUperior 1-7000
DALLAS 1: John Grant, 2100 Vaughn Bldg., 1712 Commerce St., RIverside 7-9721
DENVER 2: John W. Patten, Tower Bldg., 1700 Broadway, ALpine 5-2981
HOUSTON 25: Gene Holland, W-724 Prudential Bldg., JAckson 6-1281
LOS ANGELES 17: Gene A. Fruhling, 1125 W. Sixth St., HUntley 2-5450
NEW YORK 36: J. M. Morris, R. Bauser, 500 Fifth Ave., OXford 5 5959
PHILADELPHIA 3: William F. Buehl, Six Penn Center Plaza, LOcust 8-4330
SAN FRANCISCO 11: W. C. Woolston, 255 California St., DOuglas 2-4600
LONDON W. 1, ENGLAND: Malcom Thiele, 34 Dover St.
FRANKFURT-MAIN, GERMANY: S. Kimes, 86, Westendstrasse
GENEVA, SWITZERLAND: M. R. Zeynel, 2 Place du Port

cppc OFFERS NEW DIMENSIONS in Pancake Synchros

MOUNTING AND HOUSING DIMENSIONS TO ORDER. Here are a few typical configurations obtainable in aluminum, stainless steel, beryllium or zirconium alloys.



SIZE 23
Leads and terminals.

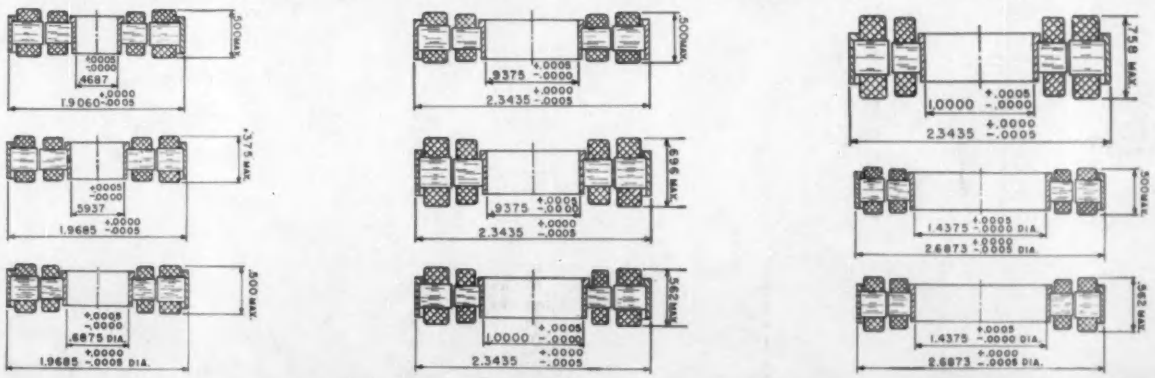


SIZE 28
Tandem unit. Transmitter and Resolver.



SIZE 37
Accuracy: ±4' max. error.

A WIDE VARIETY OF BORES AND STACK HEIGHTS, widths and diameters available from existing laminations. Below are some examples. Let us know your needs.



CIRCLE 274 ON READER SERVICE CARD

cppc

CLIFTON PRECISION PRODUCTS CO., INC. Clifton Heights, Pa.

General Sales Office: 5050 State Rd., Drexel Hill, Pa. MAdison 2-1000, TWX LNSDWN 1172(U) —or our Representatives



New Ampex FR-100C

Lightweight, single-rack recorder gives maximum performance in minimum space for your recorder dollar

Brand New Modular Solid-State Plug-In Circuits combined with the world's most proved instrumentation tape transport have enabled Ampex engineers to design an exceptionally high performance recorder with great reliability and economy of operation. The new FR-100C offers:

Performance: Frequency response is 300 kc at 60 ips direct record—20 kc with FM record. Fourteen-inch reels provide 24 minutes record time at 60 ips (with 1-mil tape). Tape handling is fully comparable to the Ampex FR-100B.

Versatility: Take your choice of direct, FM and PDM recording; six tape speeds; 1″ and ½″ tape; and up to 14 data channels and one auxiliary channel such as voice log or clocking generator.

Economy: Because the new FR-100C features modular plug-in circuits, you can tailor your recorder to your immediate needs. You can specify only the features you need now without sacrificing future flexibility.

Operation: Signal inputs and outputs are available both front and back. All connection, adjustment and calibration points are easily accessible from the front. Lightweight single-rack unit takes minimum floor space.

Ampex Reliability Built In. In addition to its greater versatility and economy, the fourth-generation FR-100C is designed to the same high standards that have made Ampex recorders the standard of excellence throughout the world. For complete specifications, write . . .

AMPEX INSTRUMENTATION PRODUCTS COMPANY • Box 5001 • Redwood City, California • EMerson 9-7111

AMPEX

CIRCLE 275 ON READER SERVICE CARD

Contents